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EXAMINATION PAPERS

FOR

511 - 58/2

SCIENCE SCHOOLS AND CLASSES.

May and June, 1886.

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EXAMINATION PAPERS

FOR

SCIENCE SCHOOLS AND CLASSES.

MAY AND JUNE, 1886.

SUBJECT I. PRACTICAL PLANE AND SOLID GEOMETRY.

EXAMINER, CAPTAIN G. S. CLARKE, R.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The constructions may be left in pencil, provided they are distinct and neat, and that the construction lines are shown. They must be strictly geometrical and not the result of calculation or trial. In the absence of those lines which are essential to a correct solution no marks will be awarded, however correct the result may appear.

Lines parallel or perpendicular to others may be drawn mechanically without showing any construction. Lines may be bisected by trial.

A single accent (′) signifies *feet*; a double accent (″) *inches*.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Questions marked (*) have accompanying diagrams.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Only *eight* questions are to be attempted.

A.

Plane Geometry.

*1. The line *ab* represents 3′.9″. Construct a scale reading inches and showing 10′.0″. The scale to be correctly figured. (8.)

2. Construct a square of 2½″ side, and through an angle draw a line cutting off one-third of its area. (8.)

*3. Describe a circle touching the given line *ab* in *c*, and passing through the given point *p*. (8.)

Solid Geometry.

4. Represent by their traces:—
   a. Two planes at right angles to each other and to the vertical plane of projection, and one of them inclined at 40° to the horizontal plane.
   b. Two parallel planes not at right angles to either plane of projection. (8.)

5. Draw the trace of a plane parallel to and 2¼″ above the horizontal plane, and determine the projections of a point in this plane 3¼″ from the ground line. (10.)

*6. Obtain the projections of two points P and Q on the given line *ab*, *a′b′*; such that P is 1·4″ from the vertical plane, and Q 2″ from the horizontal plane. Determine and write down the real length of the line PQ. (10.)

*7. *ab* is the plan of one side of an equilateral triangle lying in the given plane. Complete the plan and draw the elevation of this triangle. (12.)

*8. The plan *abcv* of a triangular pyramid standing on the horizontal plane is given. The vertex of the pyramid is in the given plane *mon*. Draw the elevation of the pyramid and also a section on the line x_1y_1. (12.)

9. Draw the plan of a hexagon of 1⅛″ side in any position, such that its plane is neither horizontal nor vertical. (12.)

*10. The T square, supposed to have no thickness, rests with the angles *a* and *b* on the horizontal plane and its own plane is vertical. Draw an elevation on a plane making 35° with the plane of the T square. (12.)

*11. *ab*, *a′b′* are the projections of a given line; *cd* is the plan, and *p′* a point on the elevation of a second line intersecting the first. Determine the traces of the plane containing the two lines. (12.)

*12. The plan and elevation of a simple solid are given. Draw an elevation on a line parallel to x_1y_1. (14.)

*13. Make a sectional elevation of the solid (Question 12) on the line AB. (16.)

Graphic Arithmetic.

*14. The given line *a* represents the product of the lines *b* and *c*. Determine and write down the length of the unit. (10.)

15. Taking one-third of *a* (Question 14) as unit, determine a line representing $\frac{\sqrt{c}}{b}$. (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

Only *eight* questions are to be attempted.

B.

Plane Geometry.

21. Two points *a*, *b* are 3⅜ miles apart. Determine the position of a point *p*, such that *pa* is 1⅝ miles, and the angle *apb* 73°. Scale 1″ = 1¼ miles. (14.)

22. Two circles of 1·8″ and 2·75″ diameter have centres 2·6″ apart. Two rods *ao*, *ob*, 2·3″ and 3·2″ long, jointed at *o*, are tangents to the circles respectively touching them at the extremities *a*, *b*. Draw the rods in all possible positions. (16.)

*23. Reduce the given figure *acdefgb* to a trapezium with *ab* as base, and its two parallel sides as *aa′* and *bb′*. (16.)

Solid Geometry.

24. Two points *a*, *b*, on the ground line are 2½″ apart. A point P is 2¼″ from *a*, 2⅞″ from *b*, and 1¼″ from the vertical plane. Obtain its projections. (16.)

*25. Determine a plane, bisecting the angle between the two given planes. (18.)

*26. Two lines are given by their figured plans. From the point *p* on one of them draw a line 2⅛″ long terminating on the other. (20.)

*27. The Maltese cross rests with the point *b* on the horizontal plane. Its plane is inclined at 40°, and the edge *ac* at 35°. Draw the plan and also an elevation on a plane parallel to the plan of *ac*. (22.)

28. A right cone, height 4″, diameter of base 3″, stands on the horizontal plane. A point starting from the base of the cone moves round its surface at a uniform speed, and rises half the height of the cone in turning round to cut the generatrix from which it started. Draw the plan and an elevation of the curve traced by the point. (26.)

*29. The plans of the edges of a four-faced right prism w horizontal axis are given. The prism is penetrated vertical square prism 2¾″ high. Draw an elevation plane parallel to the axis of the horizontal prism, sho the invisible portions of the intersection by dotted (Unit 0·1″). (2

*30. The plan of a right cylinder and of a sphere are given right cone, diameter of base 2⅛″, height 3¼″, stands o horizontal plane and touches both cylinder and sp Draw its plan and show the points of contact. (2

*31. Make an isometric view of the bolt head, the elevation half plan of which are given. (N.B.—An isometric is not to be used. Lengths to be transferred direct the given figure to the isometric lines.) (26

*32. The plan and elevation of a desk are given. Draw a f elevation on a line parallel to x_1y_1. (28

*33. Make a sectional elevation on AB of the desk (Question (28

Graphic Statics.

*34. A force of 14½ lbs. acts along the given line *ab*. Determ by construction what force acting along *cd* will have same moment about P. (18)

35. Three forces of 11, 19½ and 26 lbs. act at a point P in su directions that their resultant is nil. Draw lines rep senting the forces in direction and magnitude. (18.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementa Paper. Only *eight* questions are to be attempted.

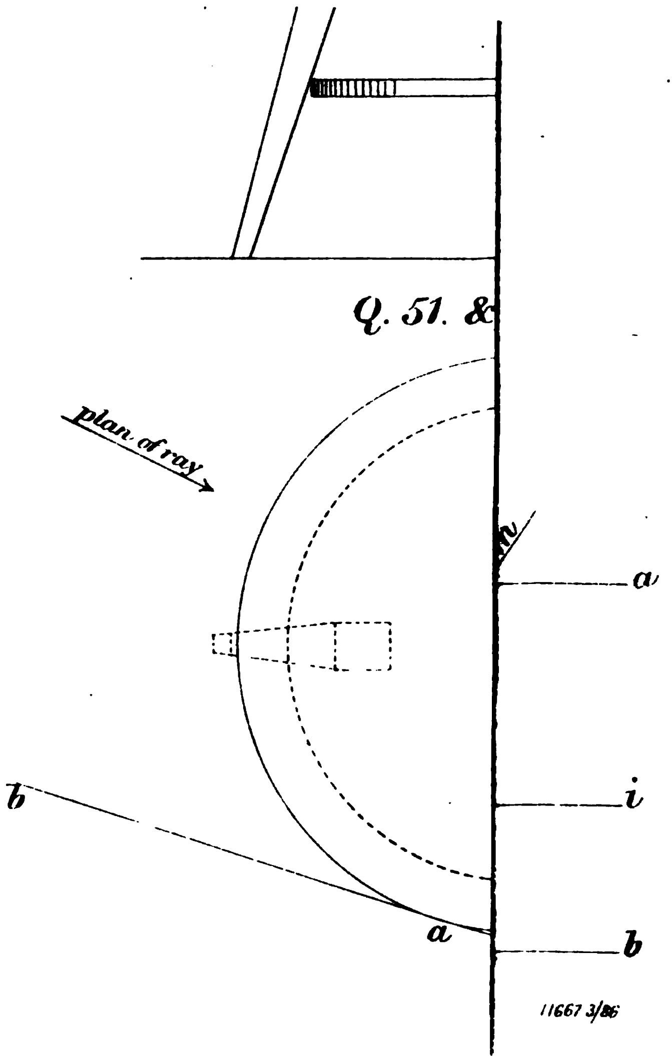
C.

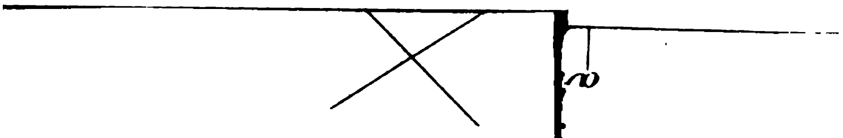
Plane Geometry.

*41. *abc* is a hoop within which revolves a circular disc turnin about A as centre; *dq* is a rod rigidly attached to th hoop at *d*; the point *q* can only move along the lin A*q*. Trace the locus of the point *p*. (40.)

*42. Draw a curve representing the velocity of the point q (Question 41) at all positions along its path. (40.)

*43. Construct an equilateral triangle which has one angle at the point *b* on the given line *ob* and the remaining angles on *oa* and *oc* respectively. (35.)





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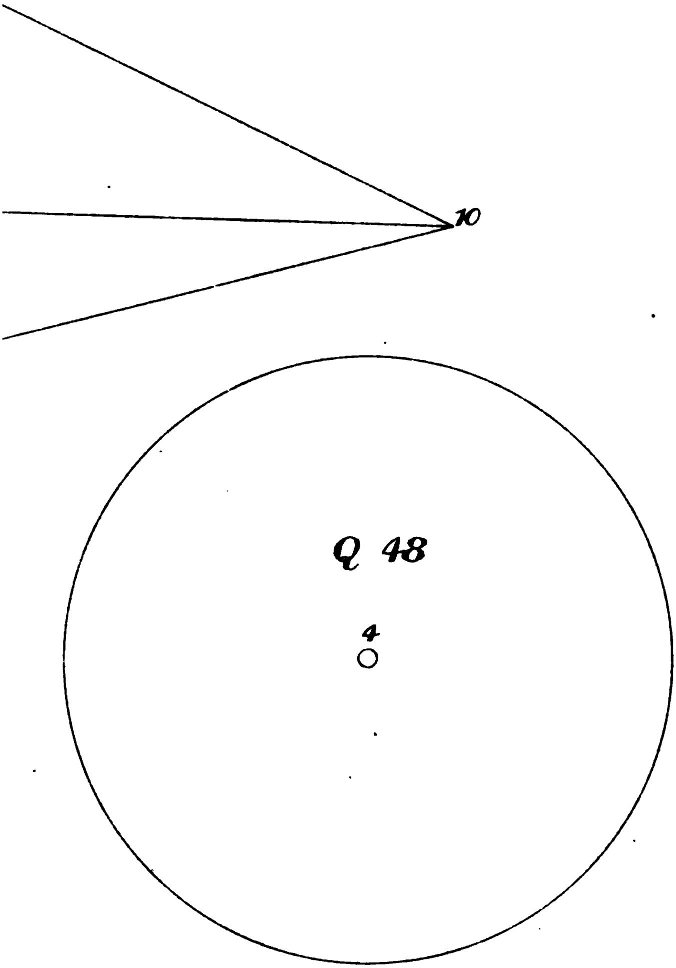


Solid Geometry.

*44. The given triangle represents the plan of one of the isosceles triangles which make up an octagon. Complete the plan and determine the side of the octagon. (40.)

*45. The given figure represents in isometric projection three equal rods, *ab*, *cd*, *ef* (2″ long), such that *ab* and *ef* are at right angles to *cd*, and the plane containing *ab* and *cd* is at right angles to *ef*. Draw the plan and any elevation of the rods, *a* and *e* being in the horizontal plane, and *cd* inclined at 30°. (40.)

*46. *aa*, *bb*, are the horizontal traces, and *ii* is the plan of the intersection of two planes at right angles to each other. Determine a third plane cutting them in two lines including an angle of 50°, and having *lm* as its horizontal trace. (45.)

*47. Draw the plan of the inscribed sphere of the given triangular pyramid. Unit 0·1″. (45.)

*48. A series of pairs of lines drawn from *p* and *q* meet on the surface of the given sphere, and each pair makes equal angles with the normal at the point of meeting. Trace the locus of the point of meeting for a short distance, and determine the two lines fulfilling the above condition, and the sum of whose length is the minimum possible. (55.)

*49. The plan of a right cylinder is given. A sphere $2\frac{1}{2}$″ in diameter rolls on the horizontal plane always touching the cylinder. Draw the plan of the locus of the point of contact. (50.)

50. Two equal right cones, height $1\frac{3}{4}$″, diameter of base $2\frac{1}{8}$″, have a common vertex. One cone rolls upon the other which stands on the horizontal plane. Draw the plan of the curve described in one revolution by a point on the base of the rolling cone. (50.)

*51. Determine the outline of the shadow cast by the table on the horizontal plane; the rays of light being parallel to the one, the plan and elevation of which are given. (55.)

*52. Draw a perspective view of the table. The ground line of the picture plane is the line *ab*. The station point is opposite, and $5\frac{1}{2}$″ from *a*. The horizon is $2\frac{1}{4}$ times the height of the table. (60.)

Graphic Statics.

*53. Forces having the given magnitudes and directions act on the horizontal beam AB. Determine the point about which the beam will balance. (40.)

*54. A load *w* of 250 lbs. is suspended from the end A of a beam AB supported at B. (1) Determine the position which must be given to a tie AC, such that it will hold AB in the given position, and that the stress it will have to bear has the same intensity as that in AB. Write down the amount of this stress. (2) What position must be given to AB and AC such that the stresses in both are 1¾ times the load *w*? (40.)

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

EXAMINERS, PROF. T. A. HEARSON, M. INST. C.E., AND
J. HARRISON, ESQ., M. INST. M.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are expected to prove your knowledge of machinery, as well as your power of drawing neatly to scale. You are therefore to supply details omitted in the sketches, to fill in parts left incomplete, and to indicate, by diagonal lines, parts cut by planes of section.

Where more than one view of the same subject is drawn, no credit will be given unless the different views are properly projected one from the other. The centre lines should be clearly drawn. The figured dimensions need not be inserted.

Your answers should be clearly and cleanly drawn in pencil. No extra marks will be allowed for inking in.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

A single accent (') signifies *feet;* a double accent (") inches.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Answer briefly any three, but not more than three, of the following questions, and draw two, but not more than two, of the examples.

Questions.

(*a*.) Give sketches showing how the cutting tool of a lathe or other machine is secured in place. (6.)

(*b*.) Make a sketch of a stud; describe how it is screwed into place, and state some circumstances under which it is used in preference to a bolt. (6.)

(*c*.) Give sketches showing one method of attaching the valve rod to an ordinary slide valve. (6.)

(*d*.) Sketch a connecting rod end with strap, gib, and cotter. Explain the use of the gib. (10.)

(*e*.) Explain the use of the quadrant for change wheels for a screw-cutting lathe shown in example 1, by making a sketch showing it in place on a lathe with wheels in gear. (10.)

(*f*.) Sketch one form of hanger suitable for supporting mill shafting. (10.)

Examples to be Drawn.

Diagram D.

1. Quadrant for change wheels for screw-cutting lathe. Draw the two views shown. Scale half size. (35.)

2. Crank-shaft. Draw the two views as shown, partly in section. Scale $\frac{1}{8}$ full size. (35.)

3. Ball bearing for Tricycle. Draw the two views as shown, partly in section. Draw full size. (35.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions above.

Answer briefly any three, but not more than three, of the following questions, and draw the example given.

(*g*.) Give sketches and a description of an adjustable spanner. (15.)

(*h.*) Show two forms of continuous lubricators for bearin describe their action.

(*k.*) Give sketches of a mortice spur wheel showing the f the rim and of the teeth, and the method of fixi latter. (

(*l.*) Make sketches showing the method of joining the pla a cylindrical boiler at a point where a longitudinal meets a ring joint. (2

(*m.*) What materials should be used in the construction excentric shown in diagram E? How is the wear excentric taken up? State the effect of this adjust on the length of the rod, and how it may be correct (2

(*n.*) The wheels of the back gear of a lathe have 50 an teeth respectively, the pitch being the same in The smaller wheel on the lathe mandril has 18 te what number of teeth should the larger wheel have? the mandril makes 100 revolutions per minute with back wheels out of gear, how many revolutions per mi will it make with the back gear in, the position and s of the belt being unaltered? (20.

Example to be Drawn.

Diagram E.

Allan's Straight-link Reversing Gear for Steam Engine. Dr the two views shown, and add an end section through the cen of the link. Draw to a scale of ¼ full size. (140.)

Honours xamination.

Instructions.

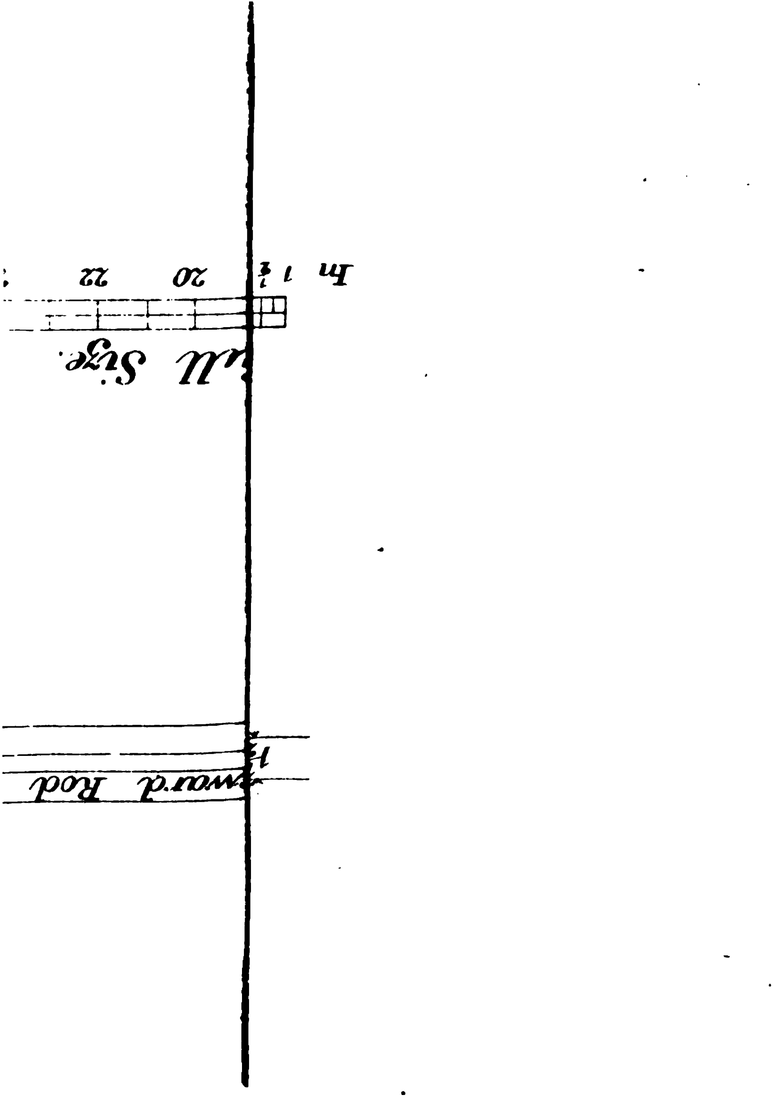
Read the General Instructions above.

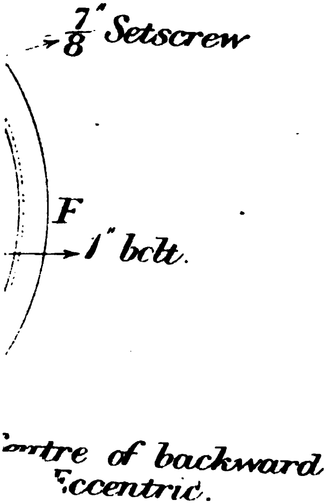
You are permitted to answer only *eight* of the following questions.

The sketches required in answer to these questions may be in pencil, and need not be drawn to scale, but should be neat and in good proportion. The written answers must be in ink, and may be written on foolscap paper, which can be obtained on application to the superintendents of the examination. Each sketch should be made in immediate connection with the answer to which it refers.

D.

LEMENT




7/8" Setscrew
F
1" bolt.
ontre of backward
Eccentric.

41. An experiment is made on the tensile strength of a bar of soft steel in the following manner:—The load is gradually increased to near the breaking point, it is then gradually removed, and gradually re-applied until the specimen breaks. A self-recording apparatus is used which traces a diagram showing the relation between the extensions of the bar, and the corresponding loads. Sketch this diagram and describe its most important features. (25.)

42. In a single-riveted lap joint exposed to tension, determine the diameter and pitch of the rivets in terms of the thickness of plate, and the three stresses f_t, f_s and f_b,

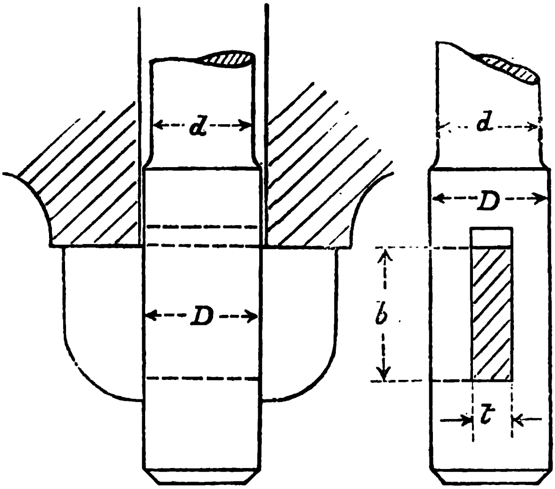
where f_t = intensity of stress on material of plate,

f_s = " " " rivet.

f_b = " bearing pressure estimated on a diametral section of rivet.

Find the diameter and pitch for ½″ plates when $f_t = 30$, $f_s = 22$, and $f_b = 42$ tons per square inch, and estimate the efficiency of the joint. (25.)

43. A foundation bolt with a square end is secured by means of a cotter as shown; determine the dimensions marked *D*, *b*, and *t*, in terms of the diameter *d*, in order that the shearing stress on the cotter may be three-fourths, and the intensity of the bearing pressure on the cotter, twice the tensional stress on the bolt. (25.)



44. Distinguish between the stiffness and the strength of a portion of a machine or structure. Explain why the transverse load which may be imposed on the parts of a structure, the transverse dimensions of which are small relatively to their length, should be proportional to the fourth power of the transverse dimensions, whilst on parts with comparatively large transverse dimensions the load applied should vary as the cube. (25.)

45. Give outline sketches showing the various ways in which long pillars are liable to yield under a load.

Quote a formula for the strength of a steel connecting rod, and determine the diameter of one 10 feet long, for an engine in which the maximum load on the piston is 70 tons. (25.)

46. Assuming the formula for the moment of resistance of a cylindrical shaft to torsion, obtain an expression for the diameter of shaft to transmit a given horse-power with a given number of revolutions per minute.

Compare the weight of shafting in a twin, with that in a single-screw ship neglecting the couplings, the lengths of the shafts and the horse-power being the same in each ship, and the speed of rotation of each twin screw being 25 per cent. more than that of the single screw. (25.)

47. State a formula which will represent the results of Wöhler's experiments on the repetition of loads.

Compare the diameters of the shafts of two engines, the power transmitted and revolutions of each being the same; in one the twisting moment fluctuates between $1\frac{1}{4}$ and $\frac{3}{4}$ the mean, and in the other between twice and $\frac{1}{2}$ the mean. (25.)

48. Determine the horse-power which may be transmitted by a leather belt 5″ wide, $\frac{1}{4}$″ thick, running at a speed of 50 feet per second, the tension on the loose side being $\frac{4}{10}$ of that on the tight side of the belt, and the stress allowed being 275 pounds per square inch. (20.)

49. Make outline sketches showing two methods by which revolving cranes are prevented from upsetting. (20.)

50. Give sketches and a description of Brotherhood's or some other flexible coupling for shafts. (20.)

51. Describe with sketches Professor Fleeming Jenkin's nest gearing, and point out the advantages possessed by it. (20.)

52. Make sketches of and describe the Worthington steam pump or some other steam pump in which no rotating shaft is employed. (25.)

53. Explain the advantage to be derived from making the length of stroke of an hydraulic engine adjustable. Describe and give sketches of a construction for this purpose. (25.)

54. Describe in detail the process of forging and machining a slotted link like that used in Stephenson's link-motion for reversing engines. (20.)

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at home. The drawings, &c., are to be sent by post to the Secretary, Science and Art Department, on or before the 19th of June. They need not be prepaid. The drawings should be as fully detailed as possible, and carefully dimensioned. Some marks will be allowed for inking-in and colouring, but more credit will be attached to good proportion and fulness of detail. Also marks will be given for notes and calculations clearly expressed.

The subject for design is an Over-head Travelling Crane for a span of 40 feet to lift 10 tons. It is to be worked by power derived either from a tumbler shaft, or high speed rope; but the construction must be such that hand power may be used when desired.

The two main beams are to be wrought-iron fish-bellied box girders; a transverse section through the centre of span is shown on accompanying diagram F, with some dimensions. These are to be adhered to.

(*a*) Estimate the thickness of plates and angle irons of girder, and the maximum stress at the centre and at quarter span.

(*b*) Make a general drawing without details.

(*c*) Show on a second drawing to a scale of 1½ inches to the foot, the arrangements for lifting to a height of 20 feet, at two speeds, in the proportion of 6 to 10.

(*d*) On a third drawing, show the arrangements for transverse travelling.

(*e*) On a fourth drawing, show the arrangements for longitudinal travelling.

(*f*) Give the speed of shaft or rope, the speeds of lifting travelling, and make an estimate of the stress on shaft or when lifting and travelling.

Credit will be given for other calculations.

The following voucher must be signed and returned with worked drawings:—

I, ______________________________

hereby certify on my honour that the drawings sent in by for the Honours Examination in Machine Construction a Drawing, have been wholly done by me, and without assista from any person.

(Signed)______________________

No.________

The above number must be quoted on each separate sheet drawings worked by you.

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary or the Advanced or the Honours paper, but you must confine yourself to one of them.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

All drawings must show a correct knowledge of construction. Neat and accurate drawing to scale is required. Where only sketches are asked for the proportions must be approximately correct, though extreme accuracy, as in drawings to scale, is not necessary. The drawings may be left in pencil, provided they are distinct and neat. No extra marks will be allowed for inking in.

You are to confine your answers *strictly* to the questions proposed.

Put the number of the question before your answer.

Answers in writing must be as short and clearly stated as possible, and close to any figures to which they may refer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question

will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

Questions marked (*) have accompanying diagrams.

The Examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt seven* questions.

You *must attempt three* of the first *four* questions. The remaining four you may select from any part of the paper.

---

*1. Segmental gauged arch over an opening in a brick wall.
Draw, to a scale of $\frac{1}{12}$, showing at A six courses of the arch bricks, starting from the springing. (11.)

*2. Section of a coursed rubble dwarf wall.
Draw, to a scale of $1\frac{1}{2}''$ to a foot, showing the construction and adding a 6″ stone coping weathered and throated. (11.)

*3. Sections of the flanges and web of a cast-iron cantilever.
Draw the section of the cantilever $\frac{1}{2}$ full size. (11.)

*4. Head of a king-post in a wooden roof truss.
Draw, to a scale of $\frac{1}{8}$, adding the heads of the principals 6″ × 4″, and a ridge board 11″ × 2″, and making any alteration you think necessary. (11.)

---

*5. Elevation of a window opening with a stone lintel, the depth of which is equal to four courses of bricks.
Draw, to a scale of $\frac{3}{4}$ of an inch to a foot, a vertical section through AA, the wall being 18″ thick, with a 9″ × 3″ wood lintel, and a discharging arch of two half brick rings. (12.)

*6. Cross section of a beam and iron flitch, which are to be formed into a flitch girder.
Draw the section of the girder, to a scale of $\frac{1}{12}$, showing $\frac{3}{4}''$ bolts by dotted lines. (12.)

7. Show by sketches the meaning of the following terms in carpenter's work:—
Birdsmouth—mortised and housed—dovetail-halving. (13.)

8. Draw a cross section, to a scale of $\frac{1}{2}''$ to a foot, showing a 9″ sleeper wall supporting a single joist floor. (13.)

*9. Plan of two successive courses of brickwork at the of a building.

Draw, to a scale of ¾" to a foot, showing the laid in English bond. (1

*10. Cross section through four common joists, 15" from c to centre.

Draw, to a scale of $\frac{1}{12}$, adding 1½" floor boards 3" × 2" ceiling joists, also sound boarding and pugg (1

11. Draw a horizontal section through a 2½" framed panelled door, to a scale of ¼.

The door to be 3' 6" wide, with 5" margins, one p to be square and flat and moulded one side, and other to be bead butt both sides. (15

12. Draw, to a scale of 3' to an inch, an elevation of a l more than half of a queen-post roof truss for a 35' s from the following details:—

Tiebeam,	5" × 9".
Principals,	5" × 6".
Queens,	5" × 3".
Straining beam,	5" × 8".

Stirrup irons and heel straps to be 2" × ¼". (16.)

13. Give a horizontal section, to a scale of ⅙, through a lit more than half of a French casement window, 3' 6" wi in an 18" wall, showing folding sashes opening outward

The inside of the frame to be flush with the inside the wall, and the joint between the frame and wall to covered with a plain chamfered architrave.

Give a freehand section of the bottom rail and sil showing how you would keep out the weather. (18.)

14. The cast iron columns supporting a floor are of 1" metal 7" mean outside diameter, and 10' long.

Rolled iron joists, 12" × 5", meeting at right angles on the heads of the columns, carry a flat concrete floor 7" thick.

Give a sectional elevation, to a scale of an inch to a foot, through the concrete and one of the joists, showing the connection of the cross girders on the head of the column. (18.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

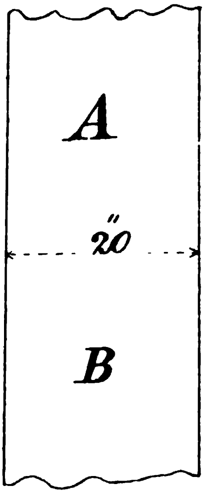
Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions.

ENTARY

1886.

(27)



(31)

21. What is the difference between a chalk lime and a lias lime? Which is the best for internal plastering, and why? (12.)

22. Explain what is meant by forge pig and foundry pig iron, and how you would distinguish between them. (12.)

23. How should cut stonework in dressings be laid, in order to guard against disintegration, and to what class of rocks does this rule apply with the greatest force? (12.)

24. Draw, to a scale of ¾″ to a foot, part of a brick wall in elevation, sufficient to show what is meant by English garden wall bond.

What is the object of this bond? (14.)

*25. End of a rolled iron joist 12″ × 6″, secured to a stone template by ¾″ rag bolts.

Draw, to a scale of 2″ to a foot, a vertical section through CC; only one of the rag bolts need be shown. (14.)

*26. Elevation of portion of an arch consisting of five half brick rings.

Draw, to a scale of an inch to a foot, showing the separate bricks, and the rings tied together at A by four lacing courses. (14.)

*27. Cross section of part of a rubble masonry wall.

Draw to a scale of ¾″ to a foot, showing at A the use of through bond stones.

At B show the use of ¾ bonds.

Under what circumstances are ¾ bonds preferable to through bonds? (16.)

*28. A rolled iron beam carrying a wall over an opening, without any relieving arch above it. Explain the nature of the stresses in the upper and lower flanges. (16.)

29. Draw, to a scale of $\frac{1}{12}$, a cross section of an egg-shaped brick sewer, 3½′ internal height.

The method of striking the curves to be shown, and a sufficient number of bricks to be drawn in to show the construction. (16.)

*30. Plan of four treads of a hanging stone stair consisting of feather-edged steps with moulded nosings.

Draw, to a scale of 1½″ to a foot, a vertical section through AA, showing 12″ treads and 6″ risers.

Show by sketches how the steps would be supported at the wall, and the iron balusters secured to the steps. (16.)

*31. Elevation of the end of a king-post roof truss resting on a 14″ brick wall.

Draw, to a scale of ½″ to a foot, making any alterations you may deem necessary, and adding common rafters with ¾″ slate boarding covered with countess slates, five courses of which are to be shown.

The overhanging eaves to be furnished with 1¼″ fascia and soffit boarding, and cast-iron ogee guttering. (18.)

32. Draw, to a scale of $\frac{1}{60}$, an elevation of an iron roof truss for a 35′ span.

Show, to an enlarged scale, the form of section you would adopt for each member of the truss, as well as the joint at the foot of the principal. (18.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions.

Of these *four* must be selected from the first *six* questions, and *four* from the rest of the paper.

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41. Name the different kinds of deals used in the building trades; state where they come from, of what trees they are the produce, and for what purposes they are most suitable. (8.)

42. Describe the process, known as Dr. Angus Smith's, for coating the insides of cast-iron pipes. (8.)

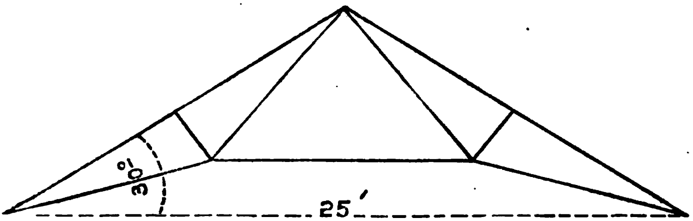
43. Explain the difference between Bessemer, blister, and shear steel, stating some of the purposes for which each is specially suited. (8.)

44. Mention the characteristics of the following bricks, and some of the purposes for which each is specially suitable:—

Malm cutters.
Dinas bricks.
Dutch clinkers.
Blue Staffords. (8.)

45. Describe by sketches the leading features of English Architecture from the latter end of the 13th to the latter end of the 14th century. (8.)

46. Ascertain the stresses on the members of the roof truss herewith, by means of a stress diagram, supposing the trusses to be 8′ apart and loaded with 40 lbs. per foot super of roof surface. (8.)



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47. Give a sketch showing how you would arrange a hot water supply from a basement kitchen range boiler to a pantry on the ground floor, a bath on the first floor, and a housemaid's closet on the second floor. (10.)

48. Give a sketch showing all the details connected with the shoring up of the side of a house 45′ high, which shows signs of bulging about halfway up. Give the scantlings and names of the different members. (10.)

49. Draw a horizontal section, one-fourth full size, through one side of a 3′ window opening, showing a cased frame and 2″ double hung sash set in an 18″ wall with a 4½″ reveal, including internal splayed and boxed linings and shutters and double-faced architraves.

The inner face of the wall to be lath and plastered on battens. (10.)

50. Draw, to a scale of 4′ to an inch, a cross section through a roof for a billiard room 20′ wide, in a private house; showing all the details of construction, including a skylight. (10.)

51. A building is to be erected on a site which necessitates the cellars being below ground, where the water will at times stand in the soil, some 3′ above the level of the cellar floors.

Give drawings showing the method of construction you would adopt. (10.)

52. Give a working drawing, in plan and section, of a double cover riveted joint in a wrought-iron bar ¾″ × 12″.

The metal will be exposed to a tensile stress of 5 tons to the inch, and it is important not to reduce the effective strength of the bar more than is absolutely necessary. (10.)

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at his own home. The drawings are to be sent by post to the Secretary, Science and Art Department, South Kensington, on or before the 19*th of June. They need not be prepaid.*

Draw up a design for a small sea-side residence standing in its own grounds at the foot of a hill, overlooking the sea and facing south.

It is to be built of a light grey rubble stone, with red brick dressings.

The foundations are rocky, and the site is exposed to heavy driving rain from the west.

The following accommodation is required :—

Dining and drawing rooms, each not less than 320 feet super; library, and 8 bedrooms; with kitchen and other offices.

All the work must be sound and good, the rooms conveniently arranged and properly ventilated.

Plans and elevations to be drawn to a scale of 8 feet to an inch, sections to twice the scale of the plans, and enlarged details to be given as may be required. A small site plan to be given, showing positions of out-offices.

The drawings must be fully dimensioned, and sufficiently complete to allow of accurate bills of quantities being taken out from them, with the exception of out-buildings, which need only be shown on the general plan.

The approximate cost of the block, ascertained by cubing out the contents, to be stated, and a short description given of the materials proposed to be employed, and of any points requiring special explanation.

The following voucher must be signed and returned with the worked drawings :—

I, ____

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Building Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed) ______________________________

No. ____________

The above number must be quoted on each separate sheet of drawings worked by you.

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them. Sketches, required to be made to *scale, must be inked in with drawing pen.*

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt ten* questions.

You must *attempt No.* 21. Two of the remaining questions may be selected from the Calculations; **and the rest from one, but not from both, of the sections of Practical Shipbuilding.**

PRACTICAL SHIPBUILDING.—SECTION I.

WOOD AND COMPOSITE SHIPS.

1. Why are the keels of wood ships frequently made of English elm? How would you trim a piece of keel? (8.)
2. What is a "floor"? How would you trim one? (12.)
3. Mention the different timbers which form a "frame," and explain clearly the method usually adopted for connecting them together at their butts. (8.)
4. What are cross-spalls? Explain how they are secured and supported, and state what purposes they serve. (8.)
5. How would you get the different timbers of the foremost part of a small wood vessel into their proper positions upon the blocks? (8.)
6. What are treenails? Where are they principally used? Explain how you would bore the hole; and prepare, drive, and finish off a treenail to ensure efficient work. (10.)
7. How would you take an account of, trim, and get in place a strake of outside plank?

   In wood ships which of the outside planks are usually first fitted, and for what reasons? (12.)
8. Explain clearly the meaning of the terms "intercostal," "continuous."

   Give examples from a composite vessel of

   (1) intercostal plates,

   (2) continuous plates.

   and state where they are fitted. (8.)
9. Explain how and when you would set off the positions of the rivet holes in the frame bars of a composite vessel.

   How would you proceed with the work of forming the holes? (8.)
10. Show by a rough sketch how the frame bar, reverse frame bar, and floor plate are connected together in a composite ship. State the sizes and pitches of rivets as well as dimensions of plates and angles. (12.)

PRACTICAL SHIPBUILDING.—SECTION II.

IRON AND STEEL SHIPS.

11. What is (1) a flush joint?
(2) a lap joint?
Show the riveting (which is to be double) in each case.
(6.)

12. Describe the difference between a "bar" keel and a "side bar" keel, and show how the butts of a bar keel are formed and riveted. (8.)

13. Show by a rough sketch how you would connect and fasten the heel of a stern post to a side bar keel. (8.)

14. Explain how and when you would set off the positions of the rivet holes in the frame bars of a mercantile vessel. How would you proceed with the work of forming the holes? (8.)

15. The material for a floor plate for a mercantile vessel supplied by the manufacturer is in two pieces. Explain clearly the work which is necessary to get the floor plate to its true shape and size. (12.)

16. Briefly explain how you would proceed with the work of framing a ship which is to be built on the bracket plate system. (12.)

17. How would you take an account of, get in place, and temporarily secure a bottom plate which has only slight curvature? (8.)

18. An iron bottom plate is $\frac{11}{16}''$ thick and 4′ wide. Sketch the disposition of rivets in edges, butts and frame stations (which are 4 feet apart), and state the size and pitches of rivets. (12.)

19. Where are angle-bulb beams usually fitted? Show how you would connect and rivet one of these beams to the frames.
(8.)

20. An angle-bulb beam is in place and secured to the frames, but it is bulged and requires straightening before the wood deck can be laid. How would you straighten the beam? (10.)

DRAWING.

21. What does Sketch No. 21 represent? It is on a scale of $\frac{1}{4}$-inch to 1 foot; enlarge it to a scale of $\frac{1}{2}$-inch to 1 foot, and show on it a water-line 8′ 9″ from the base line.
(14.)

CALCULATIONS.

22. Write down and explain Simpson's first rule for finding the area of a plane surface.

The ordinates of a portion of the water plane of a ship, in feet, are respectively 14·4; 33·6; 49·6; 57·6; 60; 57·6; 50; 40; and 25·6; the successive ordinates being 30 feet apart. The area of the portions beyond the extreme ordinates is 275 square feet.

Find the area of the whole plane in square feet and in square yards. (8.)

23. The surface of a deck which is covered with Dantzic fir 4 inches thick, is of the same area as the plane in the preceding question. What is the weight of the plank and its fastenings? (6.)

24. Define "tons per inch immersion."

The "tons per inch" at the load water plane of a ship=33·4; what is the area of the plane, and what would be the displacement in cubic feet, and in tons, of a layer 6 inches thick in the vicinity of this plane? (6.)

25. A solid pillar of iron is of uniform circular section. It is 7′ 3″ long and 2⅝″ in diameter. What is its weight? (6.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt twelve* questions.

You must attempt No. 55. The remaining questions may be selected from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

31. In trimming a piece of keel of English elm would you get rid of the sap or not? Give a reason for your answer. (3.)

32. What is a "floor"? How would you trim one? (8.)

33. Name the different timbers which form the structure at the fore end of a wood ship, and state their relative positions. (6.)

34. How are the "working" edges of the bottom planks obtained by the workmen on the frames from the "sight" edges. (6.)

35. The exterior planking of a wood ship is to be secured to the frames by copper through bolts and treenails. Explain at what stage of the work you would proceed with these fastenings; and describe how the boring of the holes, preparing the bolts and treenails, driving and finishing them off, should be done to ensure efficient work. (8.)

36. Show roughly by a transverse sectional sketch a well-known method of connecting the flat keel plate, frame, and keelson of a composite vessel. (6.)

37. Referring to the preceding question, give the sizes of plates, angle-bars, and rivets, and spacing of frames, stating the principal dimensions of the vessel you take. (6.)

38. Sketch roughly on a large scale a bolt which is used to fasten the inner thickness of bottom plank in composite ships of the Royal Navy.

What is the composition of such bolts, and how are they tested? (8.)

39. What means are taken to ensure water-tightness in the fastenings of the bottom plank of composite vessels? (6.)

IRON AND STEEL SHIPS.

40. Describe the tests to which angle-irons are subjected, to ascertain if they are fit for use. (6.)

41. Sketch roughly and describe the uses of a drift punch, a rimer, and a rose drill. Under what circumstances and for what reasons would the use of a drift punch be detrimental to good work? (6.)

42. The bottom plates of a ship are $14' \times 3\frac{1}{2}' \times \frac{11}{16}''$ and the frame space is $3\frac{1}{2}''$. Show how you would shift the butts, and show also the spacing of rivets in the butts, edges, and frame stations of one of the plates. (6.)

43. How would you take account of, prepare, get in place, and temporarily secure a bottom plate which has great curvature and twist? (8.)

44. Sketch roughly the connection of a beam with the frame, stringer plate, and wood deck, and show the fastenings. (6.)

45. Describe briefly the difference between the action of beams in wood ships, and in iron ships, when such ships are subjected to strains at sea.

Frequently it is convenient to be able to dispense with knees to lower deck beams; under what circumstances would this omission of beam knees in iron and steel ships lead to no source of weakness? (6.)

46. Explain why iron and steel ships, properly built, need no such strengthening as the diagonal riders which are fitted to wood ships. (6.)

47. Describe briefly the principal strains to which ships are liable, and state what in your opinion is the relative order of their importance. (8.)

48. Referring to the preceding question, select any one of the kinds of strains and state what means are adopted in a properly constructed ship to resist such strains. (6.)

49. The beams of a ship are in place and ready to receive the steel deck plating which is to be worked with flush joints. On the plating a wood deck is to be laid. How would you proceed with the work of plating and riveting the steel deck? (8.)

LAYING OFF.

50. How would you define the "joint" of a frame, and how would you obtain the bevellings of the timbers on each side of a joint in the square body? (6.)

51. The sheer drawing of a composite ship is made to the outside of the plank. Describe the work which must be performed before the lines from which the vessel is to be built can be placed correctly upon the floor. (6.)

52. In many mercantile ship yards it is not customary to give the mould loft draughtsman a copy of the sheer draught, but sufficient information is given to him to lay off the vessel. State what this information is, and how the work of laying off the vessel is proceeded with. (8.)

53. How are the edges of the bottom plates and longitudinals obtained, and faired, on the mould loft floor? (6.)

54. The deck of a ship has great sheer, and sections made by planes squares to the sheer are circular. Show how you would obtain the form of a beam whose sides are vertical. (6.)

DRAWING.

55. Sketch No. 55 is on a scale of $\frac{1}{2}$-inch to 1 foot. Enlarge it to a scale of 1 inch to 1 foot; state what it represents, and show the riveting in the angle bars, *a*, *a*, *a*, *a*. (12.)

CALCULATIONS.

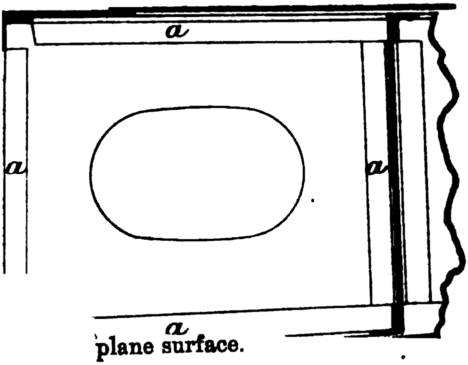
56. Describe clearly how you would proceed to find the area of a plane surface. (4.)

SUBJECT IV.

L.

— ADVANCED STAGE.

No. 55.



57. The half-ordinates of a ship's load water plane in feet are respectively ·8; 8; 16·2; 21·2; 23·6; 24·5; 24·5; 24·5; 24·5; 24·4; 23·4; 18; and 2; and the common internal is 20 feet. Find
   (1) the area of the plane;
   (2) the longitudinal position of its C.G.;
   (3) the number of tons which must be put on board to increase the draught of water by 5 inches. (8.)

58. Define the centre of buoyancy. Explain clearly how its position is found from the drawings of a ship, and illustrate your remarks by a simple example, showing how the arithmetical work is usually arranged. (6.)

59. How are "curves of displacement" constructed? What use is made of them?

The areas of five water planes of a vessel are 3,000; 3,000; 2,400; 1,800, and 1,200 square feet respectively, and the common interval between them is 18 inches.

Construct to scale the curve of displacement in tons, and mark on the curve the numerical values of the ordinates at the several water planes; the displacement of the portion below the lowest plane (which is 18" above the keel) being 25 tons. (10.)

60. A transverse bunker is filled with coals, stowed in the ordinary way; find the weight of coal it contains from the following particulars:—

Semi-ordinates in feet of the transverse section, which is of constant form throughout, are respectively 21·9; 21·5; 20·4; 17·7; and 6·2; the common interval being 3½ feet. Length of bunker in a fore and aft direction is 12 feet. 44 cubic feet of coal as ordinarily stowed weigh 1 ton. (6.)

61. A water-tight bulkhead formed of plates ⅜" thick, lap-jointed, lap-butted, single-riveted; is stiffened by angle bars 3½" × 3" × ⅜", placed vertically 30 inches apart. Find the weight of 200 square feet of the bulkhead. (8.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt fourteen* questions. You may select these from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

Wood and Composite Ships.

71. Of what kinds of wood are the stems of mercantile wood vessels made? How are the different pieces of such stems usually connected? (4.)

72. What is the "deadwood?" In what cases and for what reasons is it absolutely necessary to fit the deadwood in wood ships? (4.)

73. What is the difference between a deck hook and a breast hook? How would you trim a deck hook and fit it in place? (8.)

74. In wood ships the thickest outside plank is frequently worked in the neighbourhood of the middle of the depth of the ships. From a structural point of view this would appear to be a weak arrangement.

Briefly discuss the reasons for adopting such a disposition of material. (6.)

75. Describe the general features of composite ship construction, and state why the smaller classes of vessels in the Royal Navy are usually of composite build. (8.)

76. Specify generally, without giving dimensions, the requirements of Lloyd's Register as to
(1) floor plates;
(2) flat keel plates;
in composite vessels. (6.)

77. What kinds of wood are preferred for the outside plank of composite vessels?

In cases where it becomes necessary to use woods of an acid nature next the iron, what measures should be taken before working the wood? (6.)

Iron and Steel Ships.

78. Describe the tests to which angle-bars are subjected, to ascertain if they are fit for use, when they are of
(1) iron
(2) steel. (6.)

79. What are the objections to the use of
(1) hollow stern posts,
(2) stern posts made of several thicknesses of thin plates rivetted together? (6.)

80. Sketch roughly and briefly describe the bracket plate system of construction used in ships of the Royal Navy. (8.)

81. Show how the bottom plating is connected with, and fastened to the stem in
(1) a large mercantile vessel
(2) an armour-clad ram. (6.)

82. Show how a transverse water-tight bulkhead is plated, stiffened, and secured to the ship; and give sizes of plates, bars, and rivets. (8.)

83. Describe briefly the operations of catting and fishing an anchor, and indicate an arrangement which has been fitted, whereby these operations are dispensed with. (6.)

LAYING OFF.

84. The projections of a curve being given in the sheer and half-breadth plans, show how it can be ascertained whether the curve is, or is not, a "plane" one. (6.)

85. Describe a method of correctly laying off a head rail. (6.)

86. A ship is to be sheathed with copper; state how you would take an account of, and get in, on the ship, the line which should form the upper boundary of the copper. (6.)

87. Show, by rough sketches, a bilge keel in sheer, half-breadth, and body plans. State the reasons for the positions and directions chosen. (6.)

88. Explain a method of laying off a longitudinal frame; show clearly why the method is inexact, and where you would expect the error to be considerable. (8.)

89. How would you obtain an expansion of the outside surface of a ship from her drawings? What use is frequently made of such an expansion? (6.)

CALCULATIONS.

90. Describe clearly how you would proceed to find the area of a plane surface. Prove the accuracy of the process. (6.)

91. The half-ordinates of a ship's water plane in feet are respectively ·8; 8; 16·2; 21·2; 23·6; 24·5; 24·5; 24·5; 24·5; 24·4; 23·4; 18; and 2. The common interval is 20 feet. Find
    (1) the longitudinal position of the C.G. of the plane;
    (2) the transverse position of the C.G. of the longitudinal half of the plane. (6.)

92. Define the terms "metacentre," "centre of buoyancy." Explain and prove the formula, giving the height of the transverse metacentre above the centre of buoyancy.

    The half-ordinates of the load water plane of a vessel in feet are ·5; 5; 8; 10; 11; 12; 11; 10; 9; 6; and 1; and the common interval is 14 feet. Find the height of the transverse metacentre above the centre of buoyancy, the load displacement of the vessel being 450 tons. (8.)

93. What is meant by "moment to change trim" information must be in your possession before y compute for a particular ship, the moment t trim?

Describe clearly why it is that vessels in passi salt water to fresh water usually change trim al well as change their draught of water.

94. What is a curve of stability?

Cleopatra's Needle was brought to Englan circular pontoon, which had a metacentric he 6 inches. Draw the curve of stability of the p and mark on it in figures the lengths of $\overline{GZ}$ at suc intervals of 10°.

95. Briefly describe Heck's method of finding the stabilit ship.

96. Briefly explain the causes which produce vibration i hulls of steamships when under way; and state what circumstances the vibration may be expect reach a maximum.

How would you attempt to remedy excessive vibr in a strong ship? (1

97. The estimated maximum speed of a ship is 15 knots rudder is rectangular (approximately) in shape, is 12 in the fore and aft direction, and 160 square feet in a Find by calculation the diameter of the iron rudder h the maximum helm angle being 35°.

Sin 35° = ·574. (10.

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidates at their own homes. The drawing and calculations are to be sent by post to the Secretary, Science and Art Department, South Kensington, on or before the 19*th of June. They need not be prepaid.*

CT IV.

101. Given portions of the sheer and body plan of an iron screw vessel on a scale of ⅛-inch to a foot, make a *complete* building draught on a scale of ¼-inch to a foot, in accordance with the particulars furnished; and calculate :—

(1.) The displacement up to water lines 2½′; 4½′; 6½′; 8½′; 10½′; and 12½′ respectively.

(2.) The "tons per inch" at each of the above water lines.

(3.) The vertical and longitudinal positions of the centre of buoyancy of the vessel when floating at a draught of 12½′.

The following voucher must be signed and returned with the worked drawing :—

I, ____

hereby certify on my honour that the drawing and calculations sent in by me, for the Honours Examination in Naval Architecture, have been done wholly by me, and without assistance from any person.

(Signed) ______________________________

No. ________

The above number must be quoted on each separate sheet of drawings, &c., worked by you.

SUBJECT V. PURE MATHEMATICS, STAGES 1, 2, & 3.

EXAMINERS, REV. J. F. TWISDEN, M.A., AND
A. R. WILLIS, ESQ., M.A., D.SC.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You are permitted to answer questions from the First Stage, or from the Second Stage, or from the Third Stage, or from the Honours Paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Every page of the paper supplied for the answers may be used.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

All the work by which a result is obtained must be clearly shown *in immediate connexion with the question.* No credit will be allowed for any result, however correct it may be, unless the work be shown, so as to enable the Examiners to satisfy themselves that the candidate has understood the question, and to see by what process the result has been obtained.

Anything which you do not wish the Examiners to notice should be crossed out with the pen.

A table of logarithms must NOT be used in working these papers. All the logarithms needed will be found on the accompanying paper.

Unless you expressly state the contrary, it will be assumed that you have read GEOMETRY *in Euclid, and you will be expected to follow Euclid's sequence. Otherwise, you must state what text book you have used in geometry.*

The examination in this subject lasts for three and a half hours.

Mathematics, First Stage.

INSTRUCTIONS.

Read the General Instructions above.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

Section A.

1. Reduce to their simplest forms:—

(*a.*) $$\frac{6\frac{1}{4} - 3\frac{1}{16}}{3\frac{2}{5} \text{ of } 1\frac{1}{4}} \div \frac{12\frac{4}{15} - 11\frac{2}{3}}{3\frac{1}{3} \text{ of } \dfrac{1}{4\frac{1}{6}}}$$

(*b.*) $$(0{\cdot}1 \times 0{\cdot}01 \div 0{\cdot}0002) - (0{\cdot}6375 \times \frac{1}{1{\cdot}7} \div 0{\cdot}125).$$

(10.)

2. Extract the square root of 0·08450649, and the cube root of 6434·856. (8.)

3. Find the rent of an estate whereof $\frac{5}{12}$ths are let at £2 3*s*. 0*d*. an acre, and the remainder, consisting of 20 a. 3 r. 12 p., at £1 16*s*. 8*d*. an acre. (10.)

4. What is meant by an interest of 3½ per cent. per annum? A man sells 10 cwt. of sugar at 2¾*d*. a pound, thereby gaining 11*s*. 8*d*.; what is his profit per cent.? (10.)

5. If 1869 sovereigns are coined out of 40 troy pounds weight of standard gold, what is the weight of a sovereign in grains? and what is the value of an ounce of standard gold? (10.)

6. Find how many feet and how many metres there are in 0·581257 of a mile, having given that one metre equals 1·093638 yards. (10.)

Section B.

7. If you had a ruler and a pair of compasses, how would you bisect a given rectilineal angle? Prove that the method you employ is correct.

   How would you divide a given angle into two angles, so that one of them may be seven times as large as the other? (12.)

8. If one side of a triangle be greater than another, show that the angle opposite to the greater side is greater than the angle opposite to the less side.

   ABC is a triangle in which AB is greater than AC; the angle A is bisected by a straight line which meets BC at D; show that the angle ADB is greater than the angle ADC. (12.)

9. Show how to make a triangle whose sides shall be equal to three given straight lines, any two of which are together greater than the third. (8.)

10. ABCD is a quadrilateral in which the side AD equals the diagonal AC; show that the side BC is shorter than the diagonal BD. (10.)

11. The diagonals AC, BD of a rectangle ABCD intersect in E; show that EA equals EB.

    If CF be drawn at right angles to AC to meet AB produced in F, show that the angle AFC is equal to the angle ADB. (14.)

12. Show how to draw a triangle ABC, having given the lengths of two sides, AB, AC, and the length of the perpendicular drawn from A to the opposite side BC. What condition limits the length of the given perpendicular? How many triangles can generally be drawn to fulfil the given conditions? (14.)

Section C.

13. Simplify the following expressions and find their product:—

$$5x - (2y - x - 1) - 2\{3y - 2(x + y)\}$$

and

$$3x - 4y - 2(x - 2y) + \tfrac{2}{3}\{2x - 1 - 3(x - y)\}.$$

(8.)

14. Explain why $(a^2)^3 = (a^3)^2 = a^6$.
If $2^{3x} \times 3^{2x} = 5184$, what is the value of x?
Simplify $(a^2b)^2 \times (ab^2)^3 \div (a^2b^2)^4$. (10).

15. Write down the following expressions in factors, and find their least common multiple:—

$$4x^2 + 8x - 12,\ 9x^2 - 9x - 54,\ 6x^4 - 30x^2 + 24.$$

(10.)

16. Reduce the following expressions to their simplest forms:—

(*a*.) $$\frac{x + 2y}{x - 2y} - \frac{x - 2y}{x + 2y}.$$

(*b*.) $$\frac{1 + \dfrac{a}{b}}{\dfrac{b}{a} - 1} + \frac{a^2 - b^2}{1 - \dfrac{2b}{a} + \dfrac{b^2}{a^2}}.$$

Find the value of the former expression (*a*) when $x = -1$ and $y = \frac{1}{4}$. (12.)

17. Solve the following equations:—

(*a*.) $$\frac{x}{2} - \frac{0{\cdot}05x - 7{\cdot}5}{0{\cdot}6} = \frac{0{\cdot}25x + 3{\cdot}8}{0{\cdot}3}.$$

(*b*) $$\frac{x - y}{2} - \frac{3x - \frac{1}{2}y}{5} = \frac{1}{2}$$

$$\frac{x}{3} - \frac{y}{2} = 2.$$

(14.)

18. Find two numbers whose sum is 39 and whose difference equals a third part of the greater. (14.)

Mathematics, Second Stage.

INSTRUCTIONS.

Read the General Instructions on the first page.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

Section A.

21. Simplify

$$\left(\frac{x^5-1}{x-1}\right)^2 - \left(\frac{x^5+1}{x+1}\right)^2$$

and find its numerical value when $x\sqrt{(2+\sqrt{3})} = 1$. (25.)

22. Show that

$$\left(x-2+\frac{1}{x}\right)\left(x+2+\frac{1}{x}\right)\left(x^2+2+\frac{1}{x^2}\right) = \left(x^2-\frac{1}{x^2}\right)^2.$$

(15.)

23. If the first of two numbers diminished by the reciprocal of the second equals the second number diminished by the reciprocal of the first, show that either the numbers are equal or the one is the reciprocal of the other. (15.)

24. Find the roots of the equation

$$x^2 - 2ax + (a-b)(a+b) = 0,$$

and form the equation whose roots are the squares of the roots of that equation. (20.)

25. Find a proper fraction such that twice the denominator exceeds the square of the numerator by 2, and the product of the sum and difference of the numerator and denominator is 325. (25.)

26. Each of two vessels, A and B, contains a mixture of wine and water, A in the ratio of 7 to 3, and B in the ratio of 3 to 1; find how many gallons from B must be put with 5 gallons from A in order to give a mixture of wine and water in the ratio of 11 to 4. (25.)

Section B.

27. In every triangle the square on the side subtending an acute angle is less than the squares on the sides containing that angle by twice the rectangle contained by either of these sides and the straight line intercepted between the perpendicular let fall on it from the opposite angle and the acute angle. Prove this in the case when the perpendicular falls without the triangle.

The sides AB, BC, CA of the triangle ABC are 6, 10, and 14 units in length respectively; AB is produced to meet in D the perpendicular let fall upon it from C, and CB is produced to meet in E the perpendicular from A; find the lengths of AD and CE. (20.)

28. An angle at the centre of a circle is double an angle at the circumference standing on the same arc. Prove this when the angle at the centre is within the angle at the circumference.

ABCD is a quadrilateral inscribed in a circle; the diagonals AC, BD intersect in E; F, the centre of the circle, is within the quadrilateral; show that the angles subtended by AB and CD at F are together double the angle AEB. (25.)

29. Show how to describe on a given straight line a segment of a circle containing an angle equal to a given angle which is less than a right angle.

From a given point outside a given circle draw a straight line to cut the circle so that the chord intercepted may be equal to the radius. (25.)

30. If O is a point (not the centre) in AB, a diameter of a given circle, and COD a chord not at right angles to AB; show that the rectangle AO.OB equals the rectangle CO.OD.

Of all equal rectangles, show that the square has the smallest perimeter. (25.)

31. Show how to draw a circle to touch a given circle internally at a given point and to touch a given chord of the given circle. (20).

32. Let O be the middle point of AB, the common hypotenuse of two right-angled triangles ACB and ADB; from C and D draw lines at right angles to OC and OD to intersect at P; show that PC and PD are equal. (20).

Section C.

33. Define the logarithm of a number. What is meant by a system of logarithms?

Show that in any system of logarithms the sum of the logarithms of two numbers is equal to the logarithm of the product of the numbers.

Find the logarithm of 97·9418 × 0·0063864, and the 7th root of $\frac{13}{300}$. (25.)

34. What is the numerical value of a right angle in circular measure? Find the circular measure of an angle of 112° 43′, and the length of an arc which subtends an angle of 112° 43′ at the centre of a circle whose radius is 153 feet. (15.)

35. Show how to construct an angle of 60°, and hence find the numerical values of the sine, cosine, and tangent of an angle of 30°.

Find the value or values of θ, less than 180°, which satisfy the equations—

(*a.*) $2 \cos \theta + 1 = 0$;
(*b.*) $\tan \theta + 1 = 0$;
(*c.*) $13 \sin \theta = 3$. (25.)

36. In any triangle ABC show that—

(*a.*) $a = b \cos C + c \cos B$;
(*b.*) $a^2 = b^2 + c^2 - 2bc \cos A$.

In the triangle whose sides are 3, 4, and $\sqrt{38}$ feet in length respectively, show, without using tables, that the largest angle is greater than 120°. (25.)

37. Write down a formula giving the sine of half an angle of a triangle in terms of the sides, and, by means of the formula, calculate to the nearest second the smallest angle of the triangle whose sides are 8, 9, 13. (20.)

38. Find a formula for the area of a rectangle, having given a diagonal and an angle contained by the diagonals.

If the diagonal is 638·645 feet long, and the angle 106° 9′ 10″, calculate the area. (20.)

Mathematics, Third Stage.

INSTRUCTIONS

Read the General Instructions on the first page.

You must confine your answers entirely to Sections A and B, or to Sections A and C; and you must not answer more than *four* questions in either section.

You must not answer more than eight questions altogether.

The number of marks assigned to each question is given in brackets.

Section A

41. Solve the following equations :—

$$(a.)\quad x^{\frac{1}{m}} = ay^{\frac{1}{n}}, \qquad x^{\frac{1}{p}} = by^{\frac{1}{q}};$$

$$(b.)\quad \begin{aligned} (x + z)^2 + (y + u)^2 &= 208 \\ yz + u(x + z) &= 48 \\ z + u &= 6 \\ x + y &= 14 \end{aligned}$$

(40.)

42. Show that the greatest coefficient in a binomial expansion, when the index is a positive integer, is that of the middle or two middle terms.

Show that the coefficient of the middle term of the expansion of $(1+x)^{2n}$ is the sum of the coefficients of the two middle terms of the expansion of $(1 + x)^{2n-1}$. (35.)

43. If p rays are drawn through one point in a plane, and q rays through another point, no two of the rays being parallel, and if all the points of intersection are joined two and two by straight lines, find the number of lines, assuming that the rays are the only lines that pass through more than two of the points. (35.)

44. Show how to inscribe the least possible rhombus in a given rhombus. (35.)

45. AB is a diameter, and C any point on the circumference of a circle ABC; with C as centre a circle is described having AB as a tangent; show that the other tangents to the latter circle drawn from A and B are parallel. (35.)

46. Draw a triangle ABC; draw BD at right angles to AC, AE at right angles to AC meeting CB in E, and CF at right angles to AB, any of the lines being produced if necessary; show that the rectangles AE.CD and AB.CF are equal. (40.)

Section B.

47. (*a.*) Show that $\sin\left(\frac{3\pi}{2} - \theta\right) + \cos\theta = 0$ where θ is any angle.

(*b.*) Write down sin (A + B + C) in terms of the sines and cosines of A, B, and C respectively, and deduce from the formula that for cos (A + B + C) in terms of the sines and cosines of A, B, and C respectively. (35.)

48. Show geometrically that

$$\sin A + \sin B = 2 \sin \tfrac{1}{2}(A + B) \cos \tfrac{1}{2}(A - B),$$

when each of the angles A and B is less than a right angle.

Show that

$$\frac{\sin A + \sin 3A + \sin 5A + \sin 7A}{\cos A + \cos 3A + \cos 5A + \cos 7A} = \tan 4A.$$

(40.)

49. Show geometrically that if the value of tan A be given, nothing else being known about the angle A, there are four values of $\sin \frac{A}{2}$, and explain why the sum of the squares of those values is 2.

If $20 \tan A = 21$, find all the values of $\sin \frac{A}{2}$, $\cos \frac{A}{2}$, $\tan \frac{A}{2}$. (35.)

50. The lengths of the sides of a triangle are in arithmetical progression, and its area is three-fifths of that of an equilateral triangle of the same perimeter; find the greatest angle of the triangle.

If the perimeter is 300 feet, what are the lengths of the sides severally? (35.)

51. A wall 20 feet high bears 59° 5′ E. of S.; find the width of its shadow on a horizontal plane at the instant that the sun is due south at an altitude of 30°. (35.)

52. Explain how to deduce the formula for the area of a circle from that for the area of the inscribed polygon of *n* sides.

Two equal circles are drawn with the centre of the one on the circumference of the other; find the ratio of the area of the part of one circle which falls on the other, to that of the part which falls outside the other. (40.)

Section C.

53. Define a spherical triangle, and state clearly what is meant by the angles and sides of a spherical triangle.

Show that the sum of the sides of a spherical triangle is less than four right angles. If one angle of a spherical triangle be a right angle, show that the sum of the other two angles is less than three right angles. (30).

54. Prove the fundamental formula for expressing the cosine of an angle of a spherical triangle in terms of the sines and cosines of the sides.

Does the proof establish the truth of the formula in all cases? and, if not, in what way does it require to be supplemented? (35.)

55. Show geometrically that the sines of the angles of a spherical triangle are proportional to the sines of the opposite sides.

In a spherical triangle one side is 73° 50′, and each of the other sides 120° 55′; if it is also known that the least angle is 88° 52′ 30″, find the other angles of the triangle. (40.)

56. If in the spherical triangle ABC the angle C is a right angle, show that

$$\cos c = \cos a \cos b = \operatorname{cotan} A \operatorname{cotan} B.$$

If an arc of a great circle drawn from C meet the hypotenuse in D, show that

$$\sin^2 CD = \tan AD \tan BD. \qquad (35.)$$

57. Find the relation between the three angles of a quadrantal triangle.

Find the angle C of a spherical triangle in which $c = 90°$, $A = 60°$, $B = 30°$, having given $\sin 25° \; 39' \; 30'' = 0{\cdot}43301$. (35.)

58 Find a formula for the tangent of half an angle of a spherical triangle whose sides are given.

Calculate the smallest angle of the triangle whose sides are 32° 2′, 77° 46′, 72° 26′. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.
You may not answer more than ten questions.
The same value is attached to each question.

61. Explain why $\dfrac{x^n - a^n}{x - a} = n$, when $x = a$.

If $ax - yz = mx$, $by - zx = my$, $cz - xy = mz$, show that, when $x = 0$ and $y = 0$,

$$(c - a)(c - b) = z^2.$$

62. Find, in a form not involving surds, the result of eliminating x between the following equations:—

$$Ax^2 + Bx + C = 0$$
$$ax^2 + bx + c = 0$$

63. An arithmetical progression, a geometrical progression, and an harmonical progression have (each of them) a and b for their first two terms; if their nth terms are in harmonical progression, show that

$$\tfrac{1}{2}(n-1)(n-2)(a-b)^2 b^{n-1} \\ = ab^n + (n-2)a^n b - (n-1)a^{n-1}b^2.$$

64. If a given number $\mathrm{N} = a^p b^q c^r \ldots\ldots$, where $a, b, c \ldots\ldots$ are prime numbers, find the number of divisors of N, and show that the product of these divisors is equal to $\mathrm{N}^{\frac{n}{2}}$, where n is the number of divisors.

65. Ascertain whether the following series are convergent or divergent:—

(*a.*) $\dfrac{1}{2^n} + \dfrac{1}{3^n} + \dfrac{1}{4^n} + \ldots\ldots$ when $n > 1$;

(*b.*) $\dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{4} + \ldots\ldots$

(*c.*) $\dfrac{1}{\sqrt{2}+1} + \dfrac{1}{2} \cdot \dfrac{1}{\sqrt{3}+\sqrt{2}} + \dfrac{1}{3} \cdot \dfrac{1}{\sqrt{4}+\sqrt{3}} + \ldots\ldots$

66. Show how to describe a circle which shall pass through two given points, on the same side of a given straight line, and touch that straight line.

D is any point in the side AB of a triangle ABC; show how to draw a straight line through D, cutting AC in E, so that DE may be equal to the sum of the perpendiculars let fall from D and E upon the side BC.

67. In a given circle draw a triangle one of whose sides passes through a given point, and whose other two sides are parallel to two given straight lines. Find under what circumstances the two sides will contain an angle equal to the acute angle between the given lines, and under what circumstances they will contain an angle equal to the obtuse angle between the given lines.

68. A given line AB is divided at any point C; equilateral triangles ADC, CEB, are constructed on the same side of AB; show that for different positions of C the locus of the middle point of DE is a straight line parallel to AB, and that the centre of the circle circumscribed to the triangle CDE is a fixed point.

69. Let CA be a radius of a circle whose centre is C; draw CB at right angles to CA; show how to draw a line APQ cutting the circumference in P and CB in Q, such that the part PQ outside the circle may be of a given length.

70. Find all the values of θ which satisfy the equation—

$$\sin 3\theta - 2\sin^6\theta = \frac{8}{4}.$$

N.B.—$4\sin 18^\circ = \sqrt{5} - 1$.

71. If A, B, C are the angles of a plane triangle, show that—

$$\frac{\sin(B-C)}{\sin A} + \frac{\sin(C-A)}{\sin B} + \frac{\sin(A-B)}{\sin C}$$
$$= \frac{4\sin(A-B)\sin(A-C)\sin(B-C)}{\sin 2A + \sin 2B + \sin 2C}.$$

72. ABC is a plane triangle, r and R the radii of its inscribed and circumscribed circles. Let the internal bisectors of the angles A, B, C be produced to meet the circumscribed circle again in D, E, F, and let Δ and Δ' be the areas of the triangles ABC and DEF; show that

$$\frac{\Delta'}{\Delta} = \frac{R}{2r}.$$

73. Show how, by means of De Moivre's theorem,

$$x^{2n} - 2x^n \cos\theta + 1$$

can be resolved into quadratic factors.

The circumference of a circle (whose radius is r) is divided into $2n$ equal parts at points $P_1, P_2, P_3 \ldots\ldots P_{2n}$; show that, if chords are drawn from P_1 to the other points—

$$P_1P_2 \,.\, P_1P_3 \,.\, P_1P_4 \ldots\ldots P_1P_n = r^{n-1}\sqrt{n}$$

74. Establish the following identities, wherein each of the series is continued *ad inf.*, and $\tan\theta$ is less than unity:—

(*a.*) $2\sin^2\theta + \frac{1}{2} . 4\sin^4\theta + \frac{1}{3} . 8\sin^6\theta + \ldots$
$= 2\{\tan^2\theta + \frac{1}{3}\tan^6\theta + \frac{1}{5}\tan^{10}\theta + \ldots\ldots\}$;

(*b.*) $\sin\theta + \frac{1}{3}\sin^3\theta + \frac{1}{5}\sin^5\theta + \ldots\ldots$
$= 2\{\sin\theta - \frac{1}{3}\sin 3\theta + \frac{1}{5}\sin 5\theta - \ldots\ldots\}$.

75. If A, B, C are the angles of a spherical triangle, show that—

$$\sin\tfrac{1}{2}(A+B+C) = \frac{1+\cos a+\cos b+\cos c}{4\cos\frac{1}{2}a\cos\frac{1}{2}b\cos\frac{1}{2}c}.$$

76. Let P be an angular point of a cube, and let the three faces which meet in P touch the inscribed sphere in points A, B, C; find the radius of the small circle which passes through A, B, C, and the sides and angles of the spherical triangle ABC.

TABLES FOR THE QUESTIONS.

Logarithms of Numbers.

Number.	Logarithm.
2	·301 0300
3	·477 1213
13	·113 9434
19588	·291 9901
9	2 0123
29719	·473 0342
39176	·593 0201
7	0312
63864	·805 2561
5	2629
97941	·990 9645
2	9690

$\sqrt{2} = 1{\cdot}41421$
$\sqrt{3} = 1{\cdot}73205$
$\sqrt{6} = 2{\cdot}44949$

Logarithms of Sines.

Angle.		Log. Sin.
13°	20′	9·362 8892
	21	3 4219
18	40	9·505 2339
	41	6077
59	5	9·933 4445
63	15	9·950 8412
	16	9049
73	50	9·982 4774
	51	5140
88	52	9·999 9150
	53	9175

Logarithms of Tangents.

Angle.		Log. Tan.
16°	21′	9·467 4127
	22	8802

SUBJECT V. PURE MATHEMATICS, STAGES 4 and 5.

EXAMINER, THOMAS SAVAGE, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Fourth Stage, or from the Fifth Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The figures in descriptive geometry should not only be constructed with ruler and compasses, but the construction should in all cases be explained and its accuracy demonstrated.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Fourth Stage.—Subjects: Plane, Solid, and Descriptive Geometry and Geometrical Conics.

INSTRUCTIONS.

You are not permitted to *attempt* more than *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

1. If the sum, or the difference, of the two base angles of a triangle be equal to a right angle, prove that the perpendicular upon the base from the third angle is a mean proportional between the segments of the base (internal in the first, and external in the second case) made by the foot of the perpendicular. (16.)

2. If each side of one triangle be perpendicular to one of the sides of a second triangle, prove that the two triangles are similar. Given any point in one of the shorter sides of a rectangle, show that two rectangles may be constructed, which have an angle at the given point, and which are inscribed in the given rectangle. (18.)

3. If regular polygons of n, and $2n$, sides have the same perimeter, prove that the radius of the circle circumscribed about the first is a third proportional to the radii of the circles inscribed in, and circumscribed about, the second polygon.

   Assuming that the radius of the circle circumscribed about a regular hexagon is one-sixth of its perimeter, or otherwise, show that the area of a regular polygon of twelve sides is equal to three times the square on the radius of the circumscribed circle. (18.)

4. Prove (1) that a plane which is perpendicular to each of two intersecting planes, is perpendicular to their intersection, (2) that a plane which is parallel to each of two intersecting lines, is parallel to the plane containing the two lines. (16.)

5. How is the angle between two planes measured? If of two lines drawn from a point in the intersection of two planes, one in each plane, one only is perpendicular to the common section, prove that the angle between the two lines is greater than the acute angle between the two planes. (18.)

6. The frustum of a pyramid is cut by a plane parallel to the two ends of the frustum, and equidistant from them, and on the section thus formed a prism, of the same height as the frustum, is constructed. Show that the volume of the frustum exceeds the volume of the prism by one-fourth of the volume of a pyramid, of the same height as the frustum, cut off from the completed pyramid by a plane parallel to the ends of the frustum. (20.)

7. How are straight lines and planes represented in descriptive geometry?

   Find the horizontal projection of a line which has a given vertical projection, intersects the axis, and is parallel to a plane whose traces are given. (16.)

8. Given the projections of two lines, which do not intersect, find the traces of a plane drawn through one of them and parallel to the other. (16.)

9. Given the projections of three points, find the projections of the line which is the locus of points equidistant from the three given points. (18.)

10. Defining a conic section by means of its focus and directrix, prove that any conic section, which is not a parabola, has a second focus and directrix; and that either the sum or the difference of the focal distances of any point of the curve is constant. (18.)

11. Prove that the external angle between two tangents to a parabola is half the angle subtended at the focus by the chord of contact. What does this proposition become when the chord of contact passes through the focus?

Prove that the four tangents drawn to two equal parabolas, which have the same focus, but their axes in opposite directions, at the points where any straight line through the focus meets the two curves, form a rectangle whose area is proportional to the length of its diagonal. (20.)

12. In an ellipse, prove that the rectangle under the perpendiculars let fall from the foci upon any tangent is constant, and equal to the square of the semi-minor-axis.

Show that if perpendiculars be let fall from either focus on two tangents, the line joining the feet of the perpendiculars is at right angles to the line joining the other focus with the intersection of the tangents. (20.)

Fifth Stage.—Subjects: Descriptive Geometry, Spherical Trigonometry, Co-ordinate Geometry of two and of three dimensions.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage Paper.

You are not permitted to *attempt* more than *eight* questions, and may select them from any part of the paper.

The marks assigned to the questions are shown in brackets.

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21. The traces of a plane, and the projections of a line, in descriptive geometry, being given, construct the projections of two lines in the plane, of which the first cuts the given line at right angles, and the second is the projection of the given line upon the plane.

Prove that these two lines are at right angles to each other. (30.)

22. Construct the vertical projections of two lines, which touch a given sphere, meet the vertical plane in a given point, and have a given horizontal projection, which cuts the projection of the sphere. (40.)

23. In a spherical triangle, prove that the difference of any two angles is less than the supplement of the third angle.

If abc be the sides of a spherical triangle, and if

$$\cos a + \cos b - \cos c = 1,$$

prove that one of the angles is equal to the sum of the other two. (30.)

24. What is the area of a spherical lune, each of whose angles is A? If the arc BC cut off equal lengths AB, AC, from the arcs bounding the lune, and the area of the isosceles triangle ABC be one-fourth of the area of the lune, show that

$$\cos AB = \frac{\cos \frac{1}{2} A}{1 + \cos \frac{1}{2} A}.$$

(35.)

25. Show that in any spherical triangle,

$$\tan \frac{b-c}{2} \tan \frac{b+c}{2} \cot \frac{a}{2} = \frac{\sin (B-C)}{\sin (B+C)} \tan \frac{a}{2},$$

by proving that each of the above expressions is the tangent of the arc intercepted between the middle point of BC and the foot of the perpendicular upon BC, from the opposite angle A. Hence deduce Napier's analogies. (40.)

26. Prove that, in any spherical triangle,

$$\cos \frac{A+B}{2} \cos \frac{c}{2} = \cos \frac{a+b}{2} \sin \frac{C}{2}$$

$$\sin \frac{A+B}{2} \cos \frac{c}{2} = \cos \frac{a-b}{2} \cos \frac{C}{2}.$$

(35.)

27. Prove that the points whose co-ordinates are (8, −7), (2, 1), (−4, 9) lie in the same straight line, and find the angle between this line and the line $y=7x$. What are the equations to the three perpendiculars on the sides from the opposite angles in the triangle formed by these two lines and the axis of x? Verify the fact that these perpendiculars meet in one point. (30.)

28. Find the equation to a circle which cuts the axis of x in two given points, and passes through one given point in the axis of y. Prove that the locus of the centre of a circle, which intercepts a chord of given length on the axis of x, and passes through a given point on the axis of y, is a parabola. Determine the co-ordinates of its focus. (35.)

29. Find the equation to a hyperbola referred to its asymptotes as axes.

If a right angled triangle be inscribed in a rectangular hyperbola, prove that the perpendicular from the right angle on the hypothenuse, touches the hyperbola. (40.)

30. Find the polar equation, the focus being the pole, to a chord of a conic which subtends a given angle at the focus. Hence show that a chord of a hyperbola, which subtends at the focus an angle equal to the angle between the asymptotes envelopes a parabola. (35.)

31. Determine the co-ordinates (f, g, h) of the foot of the perpendicular let fall from the point (a, b, c) upon the plane

$$Ax + By + Cz = 0;$$

and prove that

$$\left(f-\frac{a}{2}\right)^2+\left(g-\frac{b}{2}\right)^2+\left(h-\frac{c}{2}\right)^2=\frac{a^2+b^2+c^2}{4}.$$

Give a geometrical interpretation to this result. (35.)

32. Find an expression for the shortest distance between two lines, whose equations are given.

Prove that the shortest distance between the diagonal of a rectangular parallelepiped (whose edges are *abc*) from one of the edges (*a*) which it does not meet, divides the diagonal into two segments whose ratio to each other is the duplicate of the ratio $b : c$. (40.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Fourth Stage paper.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

41. Prove that the anharmonic ratio of four points in a line is not affected by an interchange of any two of the points if the other two points be also interchanged.

Given three out of four points upon a straight line, whose anharmonic ratio is known to be the same as that of four given points upon a second straight line, construct the fourth point by the ruler only. (45.)

42. Given, in descriptive geometry, the centres and radii of two spheres, and the projection of a line, construct the traces of a plane which touches the two spheres and is parallel to the line. (65.)

43. The sides of an equilateral triangle, whose area is A, are slightly bent, so as to convert the triangle into a spherical triangle on a sphere whose radius, r, is large compared with the sides of the triangle. Prove that the area of the spherical triangle is, very nearly,

$$A+\frac{A^2}{2\sqrt{3}\,r^2}$$ (65.)

44. If three circles have a common radical axis, prove that any circle which touches two of them will cut the third at a constant angle. (60.)

45. A point P moves so that the area of the triangle, formed by joining the feet of the perpendiculars let fall from P upon the sides of a fixed triangle, is constant. Prove that P moves upon one of a series of concentric circles.

What is the maximum value of the area of the triangle, for points within the fixed triangle? (50.)

46. If four chords of a conic AA′, BB′, CC′, DD′ pass through the same point, prove that the anharmonic ratios of the pencils formed by joining ABCD and A′B′C′D′ to any point on the conic are the same.

Apply the result to inscribe in a conic a polygon of n sides, each of whose sides passes through one of n given points. (70.)

47. Through how many points, arbitrarily chosen, is it in general possible to draw a curve of the nth degree? If $np-\frac{1}{2}(p-1)(p-2)$ of the points of intersection of a given curve of the pth degree with a curve of the nth degree (n being not less than p) be known, prove that the remaining $\frac{1}{2}(p-1)(p-2)$ points of intersection are determinate. (65.)

48. Find the locus of the intersection of two planes which revolve round two fixed lines, so as to be always at right angles to each other.

Prove that the angle between the circular sections of the surface is equal to the angle between the two fixed lines. (50.)

49. In what cases will the general equation of the second degree represent (1) a cone, (2) a right circular cone whose vertical angle is 2θ?

Determine the nature of the surface,

$$(ay-bx)^2+(cx-az)^2+(bz-cy)^2=d. \qquad (65.)$$

50. If the pole of the plane of intersection of two similar and similarly placed conicoids, S and S′, with respect to S be the centre of S′, then the pole of the same plane with respect to S′ is the centre of S; and if the pole of the plane with respect to S be on the surface S′, then the centre of S is also on the surface S′. (60.)

SUBJECT V. PURE MATHEMATICS, STAGES 6 & 7.

EXAMINER, THOMAS SAVAGE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Sixth Stage, or from the Seventh Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Sixth Stage.—Subjects: Differential Calculus and Integral Calculus.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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1. Define a differential coefficient. If y represent the number of gallons of water in a leaking tank, x the number of hours since the tank was full, what does $\frac{dy}{dx}$ represent, and is it positive or negative?

Differentiate.

$$\tan^{-1}\frac{bx-a}{ax+b},\ \sin^{-1}\frac{3+4x}{5\sqrt{1+x^2}},\ \cos^{-1}\frac{1-x^2}{1+x^2},$$

and state any conclusions which may be drawn from a comparison of the results.

(30.)

2. If $u=\sin(m\tan^{-1}x)$, prove that

$$\frac{d^2u}{dx^2}(1+x^2)^2+\frac{du}{dx}(2x+2x^3)+m^2u=0,$$

and thence, by use of Leibnitz's theorem, show that if A_n denote the value of $\frac{d^nu}{dx^n}$ when x is put equal to zero,

$$A_{n+2}+(2n^2+m^2)A_n+n(n-1)^2(n-2)A_{n-2}=0.$$

(35.)

3. Apply Maclaurin's theorem to find the expansion of $\frac{\theta}{\sin\theta}$ in powers of θ as far as the term involving θ^4.

(30.)

4. When is a function of x said to be continuous? If $f(x)$ be such a function, and $f(a)=f(b)$, prove that $f(x)$ will pass through an odd number of maxima and minima values, as x changes from a to b.

If chords of an ellipse be drawn through a fixed point in the minor axis, prove that the minor axis, and the chord parallel to the major axis are either maximum or minimum chords. If they be equal to each other, prove that they are both minimum chords, and that the maximum chord is an arithmetic mean between the major axis and the latus rectum of the ellipse. (40).

5. If x and y be both given as functions of z, express $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$ in terms of the differential coefficients of x and y with respect to z.

In the cycloid, $x=a(\theta-\sin\theta)$, $y=a(1-\cos\theta)$, prove that the radius of curvature is equal to twice the normal.

(35.)

6. The equation to a curve being given in polar co-ordinates, find the angle between the radius vector and the tangent at any point, and the length of the perpendicular on the tangent.

Find the locus of the feet of perpendiculars from the pole on the tangents to the lemniscate,

$$r^2=a^2\cos 2\theta.$$ (35.)

7. Trace the curve,

$$y^3=x(x^2-4ax+5a^2),$$

pointing out the nature of the singular point at the origin. Find where the curve cuts its asymptote, and the equations of the two tangents parallel to the axis of x. Prove that the curve intercepts equal lengths on these two tangents.

(40.)

8. What is meant by integration by parts? Apply it to determine the following integrals—

$$\int_0^\pi \epsilon^x \cos 4x\, dx, \quad \int_0^1 \epsilon^{x^2} x^3 dx, \quad \int_0^\pi x^2 \cos^2 x\, dx. \qquad (35.)$$

9. Integrate

$$\int \frac{dx}{1+\cos^2 x}, \quad \int \frac{dx}{x(1+x^2)^2}, \quad \int \frac{dx}{(2+x^2)\sqrt{1+x^2}}. \qquad (40.)$$

10. Find (1) the area cut off from a loop of the curve,

$$y^2(a^2+x^2)=3x^2(a^2-x^2),$$

by the line $y=x$, (2) the length of any arc of the hyperbolic spiral $r\theta=a$. (40.)

11. Find the surface of a prolate spheroid, or the surface generated by the revolution of an ellipse round its major axis. (35.)

12. A square having been inscribed in a circle, the area made up of the square and the segment of the circle cut off by one of the sides of the square revolves round the opposite side of the square. Find the volume and the surface of the solid thus generated. (35.)

Seventh Stage.—Subjects: Differential Calculus, Integral Calculus, Differential Equations, and Finite Differences.

INSTRUCTIONS.

Read the General Instructions at the head of the Sixth Stage paper.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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21. How may (1) the asymptotes, (2) the cusps, of the evolute of a given curve be determined?

If ρ, ρ' be the radii of curvature of a curve and its evolute at corresponding points, s the arc of the involute measured from a fixed point, prove that

$$\rho'=\rho\frac{d\rho}{ds} \qquad (40.)$$

22. If three of the sides of a quadrilateral be a, b, c, respectively, prove that when the area of the quadrilateral is a maximum, the length of the fourth side will be determined by the cubic,

$$x^3-(a^2+b^2+c^2)x-2abc=0. \qquad (45.)$$

23. Find (1) the locus of the ultimate intersections of tangent planes to the surface

$$Ax^2+By^2+Cz^2=1$$

at points where it is met by a given plane (2) the locus of the intersections of the normals at the same points with the plane of xy. (45.)

24. Integrate

$$\int\frac{\cot x\,dx}{1+2\cos x},\ \int\frac{\sqrt{1+x^4}dx}{1-x^4},$$

and find the value of

$$\int_0^1\frac{x^{2n}dx}{\sqrt{1-x^2}}.$$

where n is any positive integer. (55.)

25. Find (1) the whole area of the envelope of circles, whose centres are on a given ellipse, and which pass through the centre of the ellipse (2) the volume of the closed surface

$$\left(\frac{x}{a}\right)^{\frac{2}{3}}+\left(\frac{y}{b}\right)^{\frac{2}{3}}+\left(\frac{z}{c}\right)^{\frac{2}{3}}=1.$$ (45.)

26. Define the first Eulerian integral B (l, m), and prove the relation which connects it with the Gamma function.

Hence find the value of B (l, m) when either l, m, or $l+m$, is a positive integer. (45.)

27. Integrate the linear differential equation of the first order. In the linear differential equation of the second order, show that by changing the independent variable to a properly chosen function of x, the term involving the first differential coefficient of y may be made to disappear.

Integrate the equation

$$\frac{d^2y}{dx^2}-\frac{dy}{dx}\cot x-y\sin^2x=0.$$ (55.)

28. Integrate the equations

$$(10y+7x+4)\frac{dy}{dx}+8y+5x+2=0.$$

$$\frac{d^4y}{dx^4}-2\frac{d^2y}{dx^2}+y=x^2e^x.$$

$$(mzx-nxy)\frac{dz}{dx}+(nxy-lyz)\frac{dz}{dy}=lyz-mzx.$$

(55.)

29. Find the differential equation to a curve in which the rectangle under the perpendiculars let fall from two fixed points on the tangent is equal to the square of the distance of the point of contact from the line joining the two fixed points, and thence determine the curve. (45.)

30. If $\Delta^n u_x$ vanish whenever n is greater than k, what may we infer as to the function u_x?

It is asserted that a quantity, which varies from day to day, is a rational and integral function of the day of the month, of less than the fifth degree, and that its values on the first seven days of the month are

30, 30, 28, 25, 22, 20, 20.

Examine whether these assertions are consistent. If so, assume them to be true, and find (1) the degree of the function, (2) its value on the sixteenth of the month. (40.)

31. If x be any quantity less than unity, prove that the limit of the series

$$1^n+2^n x+3^n x^2+\dots\text{ ad infinitum}$$

is,

$$\frac{1}{(1-x)^2}\left\{\Delta 0^n+\frac{x}{1-x}\Delta^2 0^n+\left(\frac{x}{1-x}\right)^2\Delta^3 0^n+\dots\right\}$$

(40.)

32. Prove that if u_x, v_x be any functions of x,

$$\Sigma(u_x v_x)=u_{x-1}\,\Sigma v_x-\Delta u_{x-2}\,\Sigma^2 v_x+\Delta^2 u_{x-3}\,\Sigma^3 v_x-\&c.,$$

Find the sum to n terms of the series

$$1^2\cos x+2^2\cos 2x+3^2\cos 3x+\dots$$

(55.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions differ but little from one another.

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41. If $x=\epsilon^{\phi+\theta}$, $y=\epsilon^{\phi-\theta}$, transform the expression

$$x^2\frac{d^2u}{dx^2}+2xy\frac{d^2u}{dx\,dy}+y^2\frac{d^2u}{dy^2}$$

into one in which ϕ, θ are the independent variables.

42. If $n-1$ of the sides of a polygon of n sides be given, prove that when the area of the polygon is a maximum, a circle can be circumscribed about it, and the n^{th} side is the diameter of the circle so circumscribed.

43. When one curve rolls upon another fixed curve determine the radius of curvature of the roulette traced out by any point, fixed in the rolling curve, in terms of the radii of curvature of the two curves and the position of the tracing point relative to the point in which the two curves touch.

If the rolling curve be a conic section, shew that at each instant during the motion, the locus of the centres of curvature of all the roulettes traced by points on the curve is a conic section.

44. Express the integral, $\int_0^{\frac{\pi}{2}} \sin^{p-1}x \cos^{q-1}x \, dx$, in terms of the Gamma function.

If V be the volume enclosed by the surface

$$\left(\frac{x}{a}\right)^{\frac{1}{2}}+\left(\frac{y}{b}\right)^{\frac{1}{2}}+\left(\frac{z}{c}\right)^{\frac{1}{2}}=1,$$

and A the area of the curve in which it meets the plane of xy, show that

$$V=\frac{4\sqrt{2}\,c}{15\,ab}A^2.$$

45. The square of the arc of a curve, measured from a given point, together with the square of the radius of curvature at the extremity of the arc, is constant. Determine the equation to the curve.

46. Show that any surface is intersected by its tangent plane in a curve which has a double point at the point of contact. If the two branches of this curve at the double point cut each other at right angles, prove that

$$(1+p^2)r-2pqs+(1+q^2)t=0.$$

47. Prove the fundamental property ot geodesic lines, and in a central conicoid, if D be the diameter parallel to the tangent at any point of a geodesic line, and p the perpendicular from the centre on the tangent plane at that point, prove that pD is constant throughout the geodesic.

If two geodesics touch the same line of curvature show that at their point of intersection they make equal angles with a line of curvature through that point.

48. Through the points $(0, a)$, (a, a) a curve is drawn of such form that $\int \sqrt{y}\, ds$ taken between these limits is a minimum. Show that the curve is a parabola, and that the value of the integral is $\dfrac{3\sqrt{3}-1}{3\sqrt{2}}a^{\frac{3}{2}}$.

49. Give a short account of the method of finding the singular solution of a differential equation of the first order (1) from its complete primitive, (2) from the differential equation; and explain the geometrical nature of the loci which are obtained, when they are not of the envelope species.

Take as an example the equation

$$y=2x\frac{dy}{dx}+\left(\frac{dy}{dx}\right)^2$$

whose complete primitive is $(2x^3+3xy+c)^2=4(x^2+y)^3$.

50. Integrate the equations of differences

$$u_{x+2}-6u_{x+1}+9u_x=x^2a^x$$

$$(x+3)^2u_{x+2}-2\frac{(x+2)^2}{x+1}u_{x+1}+\frac{(x+1)^2(x+2)}{x}u_x=0,$$

having given that a particular solution of the last is, $u_x=\frac{x}{x+1}$.

SUBJECT VI. THEORETICAL MECHANICS.

EXAMINER, REV. J. F. TWISDEN, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to *attempt* more than SEVEN QUESTIONS. You may select them from any part of the paper.

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1. State how to find the position of the centre of gravity in the following cases :—(*a*) a square lamina, (*b*) a triangular lamina, (*c*) a cone ; each body being of uniform density.
   If a body is held suspended by a thread fastened to a point of it, in what position does it come to rest? (12.)

2. Forces of 10, 13. and 16 units act at a point and are in equilibrium ; show by a diagram how they act, and note the angles between their directions. (12.)

3. A rod (AB) can turn freely round a hinge at A, and rests in an inclined position with its end B against a smooth vertical wall ; show in a diagram how the forces act which keep the rod at rest, and name them. (16.)

4. Define the moment of a force with respect to an assigned point.
   A uniform rod rests in a horizontal position on two supports 8 ft. apart, one under each end ; it weighs 6 lbs. ; a weight of 24 lbs. is hung to it from a point distant 3 ft. from one of the points of support ; find the pressure on each point of support. (14.)

5. State what is meant by the sensibility of a balance, and explain why the sensibility is great when the arms are long, and also when the centre of gravity of the beam is near the point of support. (14.)

6. Define a foot-pound of work.
   A man weighing 140 lbs. puts a load of 100 lbs. on his back and carries it up a ladder to a height of 50 ft. ; how many foot-pounds of work does he do altogether, and what part of his work is done usefully? (10.)

7. If the velocity of a body is increased uniformly in each second by 32 ft. a second, by how many feet a second is its velocity increased in one minute?
   If a velocity is 1920 ft. a second, what is it in yards a minute? (10.)

8. Write down the formula for the distance described in a given time, by a body whose velocity is uniformly accelerated.
   A body thrown upwards against gravity reaches a greatest height of 121 ft. ; find the velocity with which it is thrown up, and the number of seconds that will elapse before it returns to the point of projection. ($g = 32$). (16.)

9. A body whose mass is 10 lbs. is moving at the rate of 50 ft. a second; what is the numerical value of its kinetic energy at that instant? If from that instant it moves against a constant resistance equal to one-twentieth of its weight, how far does it go before being brought to rest? ($g = 32$.) (14.)

10. When a body is wholly or partly immersed in a liquid, what is the magnitude of the resultant pressure of the liquid on the body?

A body, whose specific gravity is 1·4 and volume 3 cubic ft., is placed in a vessel in which there is water enough to cover it; what pressure does the body produce on the points of the bottom at which it is supported? (12.)

11. Explain briefly the method of finding the specific gravity of an insoluble body by means of the balance.

If the body weighs 732 grains in vacuo, and 252 grains in water, what is its specific gravity? (10.)

12. A tube filled with water is inverted with its open end in water, no air having got in; the top of the tube is 20 ft. above the surface of the external water. If the water-barometer stands at 34 ft., what is the pressure, in pounds per square foot, at a point of the inside of the top of the tube? (1 cubic ft. of water weighs 1000 oz.)

What would be the consequence of making a hole through the top of the tube, and why would the consequence follow? (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.

You are not permitted to *attempt* more than *eight* questions. You may select them from any part of the paper.

21. State and prove the rule for finding the resultant of two parallel forces acting towards the same part on a rigid body.

Parallel forces of 10 and 20 units act towards the same part at A and B; a force of 15 units acts from A to B; find the resultant of the three forces, and show in a diagram how it acts. (20.)

22. Show that two couples, whose moments are equal and of opposite signs, are in equilibrium when they act in the same plane on a rigid body. (15.)

23. ABCD is a quadrilateral figure, P and Q are the middle points of the opposite sides AB and CD; O is the middle point of PQ; show that four forces, represented by OA, OB, OC, OD respectively, are in equilibrium. (20.)

24. ABC is a rigid equilateral triangle (whose weight is put out of the question); the vertex B is fastened by a hinge to a wall, while the vertex C rests against the wall, under B; if a given weight is hung from A, find the reactions at B and C.

What are the magnitude and direction of the forces exerted by the weight on the wall at B and C? (30.)

25. Define the coefficient of friction.

A weight of 500 lbs. is placed on a table, and is just not made to slide by a horizontal pull of 155 lbs.; find the coefficient of friction, and the number of degrees in the angle of friction by drawing it to scale; or, if you have no instruments, explain how to calculate the number of degrees. (15.)

26. Find the relation between the power and the weight in the screw press, taking into account the friction between the threads of the screw and of the companion screw. (15.)

27. Define a foot-pound of work, and a horse-power.

A steam-crane, working with 3 horse-powers, is found to raise a weight of 10 tons to a height of 50 ft. in 20 minutes; what part of the work is done against friction? If the crane is kept at similar work for 8 hours, how many foot-pounds of work are wasted on friction? (15.)

28. Find the position of a body at the end of a given time from the instant at which it is thrown with a given velocity in a given direction, the motion being supposed to take place in vacuo.

A body is thrown in a direction making an angle of 30° with the horizon, and passes through a point whose horizontal distance from the point of projection $400 \sqrt{3}$ ft., and vertical height above the point of projection 76 ft.; find the velocity of projection ($g = 32$.) (30.)

29. A particle, whose mass is 10, moving with a velocity 5, meets and impinges directly on another particle whose mass is 20 and velocity 3; the coefficient of restitution is 0·125; find from first principles the velocities of the particles at the end of the impact.

State the dynamical principles employed in answering this question, and define the coefficient of restitution. (25.)

30. A flywheel weighs 10,000 lbs., and is of such a size that the matter composing it may be treated as if concentrated on the circumference of a circle 12 feet in radius; what is its kinetic energy when moving at the rate of 15 revolutions a

minute? How many turns would it make before coming to rest, if the steam were cut off and it moved against a friction of 400 lbs. exerted on the circumference of an axle 1 ft. in diameter? ($g = 32.$) (30.)

31. Define the centre of pressure of a fluid on a plane area, and find its position in the case of a rectangular area, one edge being on the surface of the fluid.

Find where the centre of pressure of the rectangle would be, if its plane were vertical and its upper edge (which is horizontal) below the surface of the water at a distance equal to the height of the rectangle. (25.)

32. Given the specific gravities of two liquids, show how to calculate the specific gravity of a mixture of given volumes of the two liquids, assuming that the mixture takes place without change of volume.

Three pints of a liquid, whose specific gravity is 0·8, are mixed with five pints of another liquid, whose specific gravity is 1·04; find the specific gravity of the mixture, (*a*) if there is no contraction, (*b*) if on mixture there is a contraction of 5 per cent. of the joint volumes. (20.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.

You are not permitted to *attempt* more than *eight* questions. You may select them from any part of the paper.

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41. Find the position of the centre of gravity of a very fine piece of wire, bent into the form of a circular arc of given radius.

Calculate (by Guldin's rule) the area of the surface of the solid formed by the revolution of the arc of a quadrant of a circle round its chord. (40.)

42. A given force acts at right angles to the plane of a given couple; show that the three forces cannot be reduced to fewer than two, and that the reduction can be effected in an infinite number of ways.

Let ABCD, ABEF be two faces of a cube; a given force acts along the edge BC, and an equal force along the diagonal AE; show how to resolve them into a couple and a force at right angles to the plane of the couple. (60.)

43. A and B are two points in a horizontal line; the ends of a thread, whose length is less than 3 AB, are fastened to A and B; let C and D be points dividing the thread into three equal parts; if equal weights are fastened at C and D, find the tensions of the parts of the thread. (40.)

44. A rough cylinder is placed endwise on a rough horizontal plane, against which it is pressed by a given weight; find the moment of the couple which will just turn it against the friction of the plane. (40.)

45. Find an expression for the radius of curvature at any point of the neutral axis of a prismatic beam slightly bent by forces, acting in a plane containing the axis of the beam, at right angles to the axis in its undeflected state.

A, B, C, D are four points taken in order along the axis of a beam of uniform cross section; the beam is kept at rest by forces acting at these points; those at A and B form a couple, and so do those at C and D; the weight of the beam is neglected; show that the radius of curvature of the axis has the same value at all points between B and C. (50.)

46. Define the virtual moment or virtual work of a force. If X and Y are rectangular components of a force P, show that the virtual work of P equals the sum of the virtual works of X and Y.

Apply the principle of virtual velocities to find the relation between the power and the weight on a rough inclined plane, when the power is about to make the weight slide up the plane. (50.)

47. If x and y are the co-ordinates of a moving point, explain briefly why its velocities parallel to the axes of x and y are $\frac{dx}{dt}$ and $\frac{dy}{dt}$.

A rod moves with its ends A and B in two fixed rectangular axes, Ox and Oy, respectively; given, at any instant the velocity of A along Ox, find that of B along Oy, and the velocity and direction of the motion of the middle point of the rod. (50.)

48. Find the moment of inertia of a square about one edge, and deduce from it that of a right angled isosceles triangle about the hypotenuse. (40.)

49. Define the centres of suspension and oscillation of a compound pendulum; state exactly what is meant by their convertibility and prove it. (40.)

50. A perfectly flexible chain hangs over a smooth fixed point, and is allowed to move under the action of gravity; when it is in any given position find;—(a) the acceleration of its velocity, (b) the tension at a given point of its length.

Verify the formula for the tension by deducing from it (*c*) the tension at the middle point when the hanging ends are equal, and (*d*) the tension at any point when the chain is just leaving the smooth point. (60.)

51. Assuming the temperature of the air to be constant, show that the difference between the altitudes of two stations equals

$$H(\log h - \log h_1),$$

where h is the height of the barometer at the lower, and h_1 its height at the upper of the two stations respectively.

What quantities would have to be determined in order to assign a numerical value to H? What is H commonly called, and what is (approximately) its numerical value in feet? (50.)

52. On a vertical wall of a reservoir a circle is described with its centre on the surface of the water; find the centre of fluid pressure of the part under water. (40.)

SUBJECT VII. APPLIED MECHANICS.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You may not *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

1. When a body is raised through a given height, how is the work done estimated? A body weighing 8 cwt. is drawn along 100 feet up an incline, which rises 2 feet in height for every 5 feet along the incline; the resistance of friction being neglected, find the work done. (15.)

2. A capstan is worked by two men on opposite sides, each pressing a capstan bar with a force of 30 lbs. at a distance of 4 feet from the axis. The rope is wrapped round a drum whose diameter is 1 foot; find the pull on the rope which would balance the pressure on the capstan handles. Make a diagram showing the action of the forces, and find the pressure upon the central shaft on which the capstan turns. (20.)

3. What is the *pitch* of a screw? Distinguish between a *single* and a *double-threaded* screw; in what cases would the latter be used? Why are holding-down bolts made with angular threads? (15.)

4. A pinion with 20 teeth works in a straight rack, the distance from centre to centre of the teeth in the pinion being ½ inch. The pinion is driven by a ratchet wheel fixed on the pinion shaft, and the ratchet wheel has 40 teeth; find the advance of the rack in inches for each tooth moved through by the ratchet wheel. (15.)

5. A tackle is formed of two blocks, each weighing 15 lbs., the lower one being a single movable pulley, and the upper or fixed block having two sheaves; the parts of the cord are vertical, and the standing end is fixed to the movable block; what pull on the cord will support 200 lbs. hung from the movable block, and what will then be the pressure on the point of support of the upper block? Sketch the arrangement. (20.)

6. Sketch a Fly-press, explain its action, and state for what purposes it is chiefly used. Find, in foot-pounds, the amount of work accumulated in a body which weighs 80 lbs. and has a velocity of 20 feet per second. (20.)

7. In the vertical plane side of a tank holding water there is a rectangular plate whose depth is 1 foot and breadth 2 feet, the upper edge being horizontal, and 8 feet below the surface of the water; find the pressure on the plate. The weight of a cubic foot of water is 62·5 lbs. (15.)

8. Describe, with a sketch, an ordinary suction or lifting pump, and explain its action. (15.)

9. Sketch a section through a hydraulic press, and describe its action by reference to your drawing. Give the diameters of the plunger and ram which you would adopt in order

that a load of 2 tons on the ram may be raised by a pressure of 20 lbs. at the end of the lever handle, which works the force-pump, and acts with a leverage of 8 to 1. (20.)

10. What is the object of using speed pulleys? Show their application in a foot lathe, and the manner in which the motion of the workman's foot is converted into the circular motion of the mandril. Sketch the arrangement. The diameter of the largest pulley on the crank shaft being 2 feet, and that of the smallest pulley on the mandril being 3 inches; find the number of rotations of the mandril for each complete rotation of the crank shaft when these pulleys are connected by a band. (20.)

11. Explain why iron girders are made with flanges at the top and bottom united by a web of metal, instead of being rectangular in section. What condition decides which of the two flanges shall contain the most metal? (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

21. What meaning do you attach to the phrase *Horse Power?* A fire engine pump is provided with a nozzle, the sectional area of which is 1 square inch, and the water is projected through the nozzle with a velocity of 130 feet per second; find the horse power of the engine required to drive the pump, irrespective of the loss by resistance of the working parts. The weight of a cubic foot of water is 62½ lbs. (40.)

22. Describe some simple weighing machine with levers in a frame underneath the scale pans. The scale pan being arranged with a parallel motion, so as to remain horizontal during the weighing, show that it is indifferent on what part of the scale pan the substance is placed. (35.)

23. What is the object of using guide pulleys in machinery? Mention any instance of their application, and show how the direction of their axes is ascertained. (30.)

24. Describe the principle of the hydraulic accumulator, showing, by reference to a sketch, a mode of constructing it. (35.)

25. In a compound wheel and axle, let the diameter of the large axle be 6 inches, and that of the smaller axle 4 inches, and the length of the handle 20 inches; find the ratio of the velocity of the handle to that of the weight raised. (35.)

26. In mechanism for causing a tool to traverse the cross slide of a planing machine, the pitch of the screw is $\frac{1}{4}$ inch, and the ratchet wheel driving the screw has 40 teeth. Find the advance of the cutter for an advance of 3 teeth on the ratchet, and sketch the arrangement, showing how the feed motion is worked. (40.)

27. What is an epicyclic train? Two wheels, A and B, are so mounted as to form an epicyclic train, and A is a dead wheel having 80 teeth, while B has 20 teeth. Find the number of turns made by B for each rotation of the arm. (40.)

28. Describe, with sketches, the masked ratchet wheel combination, whereby the main ratchet is advanced one tooth for every alternate forward stroke of the driving paul. (35.)

29. A beam of fir is built into a wall at one end, and projects 6 feet from the wall. The width of the beam is 4 inches; find its depth to bear safely a load of 1200 lbs. uniformly distributed along its length. Assume that a bar of fir 1 foot long, 1 inch broad, and 1 inch deep will break under a load of 125 lbs. when fixed at one end and loaded at the other end, and that the safe load is $\frac{1}{5}$ the breaking load. (40.)

30. Why are the separate strands in a hempen rope twisted in the opposite direction to the twist of the rope? Explain, with sketches, the construction of a machine for forming hempen strands into a rope. (40.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You may not *attempt more than six* questions.

The value attached to each question is shown in brackets after the question.

41. Sketch and describe a friction brake as applied to a crane. The lever applied to the strap is a bent lever, of which one arm is 2 feet 11 inches long, and the other arm, which is at right angles to it, is 3¼ inches long, the diameter of the friction drum being 2 feet; find the tension of the movable end of the strap when a pressure of 100 lbs. is applied to the handle, and the tension at the fixed end for a given coefficient of friction. (65.)

42. The lower boom of a Warren girder, supported at both ends, is divided into three bays. The upper boom has two bays, and the bracing bars are each inclined at 60° to the horizon. Find by graphic construction or otherwise the stresses in the several pieces when the frame is loaded with 1000 lbs. at the middle of the top boom. (65.)

43. Describe, with a sketch, the mechanism which renders Watt's pendulum governor applicable to the regulation of a water-wheel. What is the difficulty to be overcome? (65.)

44. Sketch and describe a shaping machine worked by a slotted bar, and having a quick return. If the bar or lever vibrates about one end under the action of a driving crank 6 inches long, and the time of the forward stroke be three times that of the return stroke, what would be the distance between the centres? Compare the angular velocities of the crank and lever at any instant. (75.)

45. In a machine for sawing timber into planks, describe and explain a contrivance for feeding on the log of timber at the end of each stroke of the saw by a wheel acting as a ratchet wheel, but without teeth. (60.)

46. An epicyclic train consists of three wheels, A, B, C, taken in order, and in gear with each other. The first wheel A has 75 teeth, B has 60 teeth, C has 45 teeth, also the driver A rotates three times in a minute, and the arm rotates four times in a minute, and in the opposite direction. How many rotations do B and C make respectively in one minute? (65.)

47. Describe, with sketches, the construction of a hydraulic crane, with two powers, to lift 5 tons. (65.)

SUBJECT VIII. SOUND, LIGHT, AND HEAT.

EXAMINERS, PROFESSOR W. GRYLLS ADAMS, M.A., F.R.S., AND
PROFESSOR A. W. REINOLD, M.A., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary or the Advanced or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions. Of these not more than *four* may be selected from the same section.

The value attached to each question is the same.

SECTION I.

1. Describe the construction of the air-pump, and explain its action.
2. Two equally stretched strings of the same thickness, one of steel and the other of catgut, give the same note when struck. Which of them is the longer? Give reasons for your answer.
3. Explain how to determine the velocity of sound in a solid, and state clearly on what properties the velocity depends.

4. A tuning fork, making 384 vibrations per second, is held over a cylindrical jar filled with air, in which the velocity of sound is 1100 feet per second. What must be the length of the jar in order that it may be best adapted to resound to the fork?

   What is the length of the wave sent out by the fork?

5. A stopped organ pipe 4 feet long, and an open organ pipe 12 feet long, are sounded. How are the notes related to each other? Do they differ from each other in quality, and, if so, why?

SECTION II.

6. Describe an experiment made with the shadow photometer to test the illuminating powers of two sources of light.

7. What is the difference between a *real* and a *virtual* image of an object? Explain and illustrate by a sketch the formation of one of each kind.

8. A thick plate of glass is interposed obliquely between a candle and the observer's eye. Will the apparent position of the candle be altered by the glass? Draw a picture illustrating your answer.

9. Explain, and illustrate by a figure, the path of a beam of light from any source which is reflected by a concave spherical mirror.

10. Explain, and illustrate by a figure, what happens to a ray of sunlight in passing through a triangular prism. Under what circumstances will the ray fail to pass through it?

SECTION III.

11. State the law governing the expansion of a gas at constant temperature under varying pressures, and show how the law may be proved experimentally.

12. Under what circumstances is an alcohol thermometer used instead of a mercurial thermometer? How is an alcohol thermometer graduated?

13. What is meant by *unit of heat?* If the specific heat of iron be $\frac{1}{9}$, and 5 lbs. of iron be cooled down from the temperature of boiling water to the temperature of melting ice, how many units of heat are evolved?

14. When is a space said to be saturated with vapour, and what is the effect of (1) a rise, (2) a sudden fall in temperature in a space which is so saturated?

15. A flask containing water is heated. When the water boils, the flask is carefully closed with a cork and removed from the flame. Explain why, when the flask is dipped into cold water, the water inside begins to boil again.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions. Of these not more than *four* may be selected from the same section.

The value attached to each question is the same.

SECTION I.

21. Four strings of the same length and material, but of different thicknesses, are stretched on a violin and tuned so as to give successive fifths. If the tension be the same, compare the thicknesses of the strings.

22. In the last question, what must be the tension on the several strings that they may all give the same note?

23. State the laws of the transverse vibrations of rods fixed at one end. What relation holds between the numbers of vibrations for the successive overtones in such rods?

24. Explain how to determine experimentally the velocity of sound in hydrogen?

25. What conditions are necessary in order that two sound waves reaching the ear by different paths may produce silence?

SECTION II.

26. What must be the angle between two plane mirrors in order that an incident ray which is parallel to one of them may, after two reflections, be parallel to the other?

27. Roemer determined the velocity of light by observations of the eclipses of one of Jupiter's moons. State clearly the nature of his observations, and the reasoning by which the velocity of light was deduced from them.

28. A ray of light is incident perpendicularly upon one of the two faces of a right-angled isosceles prism which bound the right angle. Draw a picture showing the subsequent path of the ray, and give reasons for your construction.

29. State generally the effect of a lens upon a ray of light passing through it. Show how with a double convex lens an image of a lighted candle may be seen (1) inverted and magnified, (2) inverted and diminished, (3) erect and magnified.

30. Describe the principal parts of a spectroscope.

SECTION III.

31. Explain what is meant by the dew-point? How does the dew-point show the amount of vapour in the atmosphere? Describe the mode of action of a dew-point hygrometer.

32. A hundred cubic inches of air weigh 31 grains when the temperature is 0° C. What will be the weight of the same volume of air when the temperature is 20° C. and the pressure one-third of its original amount, the coefficient of expansion being $\frac{11}{3000}$?

33. What is meant by "latent heat of vaporisation"? If the latent heat of vaporisation of water be 966 when one degree Fahrenheit is the unit of temperature, what will it be when one degree Centigrade is the unit? Would your result be different if the unit of mass had been changed?

34. Describe the construction and action of maximum and minimum thermometers.

35. Explain the difference between the specific heat of air at constant pressure and its specific heat at constant volume. Which of them is the greater, and why?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are expected to attempt all the questions.

The value attached to each question is the same.

41. Give the number of vibrations corresponding to each note of the diatonic scale ($c' = 264$). Point out clearly the advantages and disadvantages of the equally tempered scale. What other scales have been used or proposed?

42. What are the optical characteristics of a rhomb of Iceland spar? Give Huyghens' construction for the course of the ordinary and extraordinary rays, and state in what planes

these two rays are polarised. What must be the plane of incidence that both rays may be ordinarily refracted?

43. Explain clearly in what ways the spectroscope has been used to determine the constitution of the sun, and discuss the evidence obtained by its means.

44. Describe the methods which have been employed for determining the amount of heat developed by the union of oxygen and hydrogen in forming water.

45. Describe the experiments necessary for determining the thermal conductivity of a metal like copper, and point out clearly how the value of the thermal conductivity is deduced from the data of the experiment.

Practical Examination.

You are required to answer *four* of the following questions.

1. Compare velocities of sound in various materials.
2. Make a weight thermometer and determine the co-efficient of expansion of mercury.
3. Determine the specific heat of a solid.
4. Determine the focal lengths of a compound lens and of its parts.
5. Determine the index of refraction and the curvatures of a double convex lens.
6. Determine the angle of a prism (two methods).
7. Determine the angle of a prism and its refractive index for sodium light.
8. Determine the wave length for sodium light.

SUBJECT IX. MAGNETISM AND ELECTRICITY.

EXAMINERS, PROFESSOR FREDERICK GUTHRIE AND
PROFESSOR G. CAREY FOSTER, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than *eight* questions.

You may select only *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

1. If a compass needle is deflected when a steel bar is brought near it, how can you find out whether the deflexion is due to magnetism already possessed by the bar, or to the bar becoming magnetised by the compass needle at the time of the experiment?

2. Two equal bars of steel, after having been equally magnetized, are kept for some years in a vertical position, one (a) with its south-seeking pole upwards, the other (b) with its north-seeking pole upwards. The bars are so far apart that they do not act on one another; which of the two bars would you expect to find had kept its magnetism best, and why?

3. You have given to you two rods, one of soft iron, the other of hard steel; also a compass needle and a bar magnet. Describe experiments with the things provided whereby you could find out which was the iron and which the steel rod.

4. A piece of soft iron, placed in contact with both poles of a horse-shoe magnet at the same time, is held on with more than twice the force with which it would be held if it were in contact with only one pole of the same magnet. Why is this?

Frictional Electricity.

5. A stick of sealing wax, held in the hand and rubbed with dry flannel, is found to become electrified. A brass rod after being treated in the same way shows no electrification. How do you account for the difference?

6. A stick of sealing wax, having been rubbed with flannel, is found to be negatively electrified. How, by means of it, would you charge a proof plane with positive electricity?

7. If an electrified piece of metal is made to touch a gold-leaf electroscope, the leaves separate and, on taking the metal away, they remain separate. But if the electrified metal is only brought *near* to the electroscope, and then taken away, the leaves separate when the electrified metal is near, but fall together when it is taken away. Why is there a lasting effect on the gold leaves in one case and only a temporary effect in the other case?

8. Two insulated metal spheres are brought so as to touch one another. A positively electrified glass rod is brought near to one of the spheres and, while it is there, the other sphere is taken away. The glass rod is now taken away. On bringing the spheres near together again, a spark passes between them. Give the reason for this.

9. To protect a gold-leaf electroscope from being acted on when an electrical machine is at work near it, it is sufficient to cover the electroscope with a thin cotton cloth. How is this?

Voltaic Electricity.

10. How could you boil water by means of the current from a voltaic battery? Give a sketch of the apparatus you would use.

11. One end of a copper wire is fastened to the copper end of a battery, and one end of another copper wire is fastened to the zinc end of the battery. What happens if the other ends of these two wires are put side by side (but not touching) into a solution of sulphate of copper?

12. A number of galvanic cells are connected together in a row so as to form a battery. This row is laid on a table so as to lie N. and S. The zinc is to the N. The poles of the battery are connected together by a wire, which passes from one pole, up one wall of the room, across the ceiling, and down the opposite wall to the other pole of the battery. How will a magnetic needle be affected which is placed under the table and just below the battery?

13. How is it that a galvanometer with astatic needles is more sensitive than the same instrument would be if furnished only with a single needle?

14. If a charged battery is to be kept for some time ready for use, why is it important to take care that the ends of the battery are not connected together outside the battery?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *eight* questions.

You may select only *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

21. A circular steel disc is magnetized, so that one of its diameters is its magnetic axis. How could you find the magnetic axis by observing the position which the disc takes when it is hung by a silk thread so that it lies horizontally?

22. Two equal and equally magnetized darning needles are thrust through a wooden match at right angles to it; and with the similar poles pointing in opposite directions. If when the match is hung by one end from a silk fibre the needles are not in the same vertical plane, will the combination be astatic? If not, how will it place itself, and why?

23. A bar magnet is laid at the middle of a circle on the floor. Explain a method by which the direction could be found, in which a small compass needle placed at any point on the circumference of the circle would set itself. (The earth's magnetic action may be neglected in comparison with that of the magnet.)

24. Find the total magnetic force of the earth at a place where the horizontal component is 0·223 and the dip 60°.

Frictional Electricity.

25. You have two metal pots on separate insulating stands; also a metal ball carried by an insulating stem; also a wire connected with the earth. Suppose the ball, or one of the pots, to be slightly electrified. Describe and explain

a process by the repetition of which you could electrify the two pots more and more strongly, one positively and the other negatively.

26. A large insulated metal ball at a great distance from all other conductors is electrified. And then by touching it with an earth-connected wire it is discharged. It is again electrified to the same degree as before, and then discharged by bringing it into contact with a wall of the room; why does the second discharge produce less heat than the first?

27. Three metal balls, the diameters of which are respectively 5, 7, 12 inches, are all connected together by very fine wires but are otherwise insulated. If the smallest ball has a charge of 10, what are the charges of the other balls?

28. Describe and explain the use of any form of "Attracted-disc Electrometer." Show what it measures, and explain the action of the "Guard-ring."

29. The inside of a Leyden jar is connected with the prime conductor of an electrical machine, and the outside with the rubber of the machine, and also with a brass ball fixed at $\frac{1}{10}$ inch from the prime conductor. If the jar is at first without charge, ten turns of the machine are required to cause a spark to pass between the conductor and the ball. If now (the inside of the jar remaining, as before, connected with the prime conductor) the outside is insulated and connected with the inside of an exactly similar jar, the outside of which is connected with the rubber and the brass ball; show how many turns of the machine would be required to make a spark pass.

Voltaic Electricity.

30. Two exactly equal pieces of copper are drawn into wire; one into a wire 10 feet long, and the other into a wire 20 feet long. If the resistance of the shorter wire is 0·5 ohm, what is the resistance of the longer wire?

31. A thick copper wire and a thin copper wire, of such lengths as to have the same resistances, are joined end to end and used to connect the terminals of a battery, so that the same current flows through them both. Explain why the thin wire becomes hotter than the thick one.

32. A metal ring is put round the end of a bar magnet. Upon bringing a mass of soft iron near to this end of the magnet, a current is produced in the ring. Show what motions (*a*) of the magnet and (*b*) of the ring will produce a similar current in the absence of the soft iron.

33. A battery is employed to drive a magneto-electric engine. Does the rate of consumption of zinc increase or decrease (and why) if the speed of the engine is increased by lessening the work it has to do?

34. Six Grove's cells, connected (*a*) in a single series and (*b*) as two series of three each, are used to decompose water in a voltameter. If there is no local action in the battery, show how much zinc is dissolved in each case (*a*) and (*b*) in the whole battery while one grain of hydrogen is evolved in the voltameter.

Take sulphate of hydrogen (sulphuric acid) as H_2SO_4 (98) and sulphate of zinc as $ZnSO_4$ (161).

Honours Examination.

Full marks can only be got by answering all the questions; but good answers to some of the questions are likely to gain more marks than hasty attempts to answer all of them.

The value attached to each question is the same.

41. Given a sufficient length of telegraph cable consisting of a single thick copper wire uniformly covered with a cylindrical coating of insulating material, describe and explain measurements and experiments that would enable you to determine the *specific inductive capacity* of the insulator.

42. The specific inductive capacity of the dielectric of any condenser being known, state and explain how you could determine experimentally the *specific resistance* of the dielectric.

43. Explain fully the theory of "Wheatstone's Bridge." Describe the form of Wheatstone's Bridge with which measurements are made by adjusting a movable contact upon a graduated wire, showing what precautions and corrections are required, and how these can be made.

44. Describe and explain fully the experiments and calculations needed for determining the *electro-chemical equivalent* of an electrolyte.

45. Explain the sense in which the term "Absolute" is used in connexion with measurements of electrical magnitudes. Describe and explain an experimental method of determining, in absolute measure, the *resistance* of a conductor.

Practical Examination.

You are required to answer *all* the following questions.

1. Determine by the method of deflection and oscillation (Gauss's method) the moment of the magnet given to you; and the strength of the magnetic field at the place of the experiment.
2. Determine by means of the Tangent Galvanometer and Copper Voltameter the electro-chemical equivalent of copper, adopting the magnetic field as determined in 1.
3. Determine the resistance and capacity per kilometer of the cable supplied.
4. Find the specific resistance and the specific inductive capacity of the insulating material of the cable 3.
5. Measure the resistance of the bobbin of wire supplied to you.

SUBJECT X. INORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC.,
PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

C = 12. Ca = 40. Cl = 35·5. Cu = 63·0. H = 1. O = 16. Zn = 65·0.

1. Explain the meaning of the terms analysis and synthesis, and give two cases of each in illustration. (8.)
2. Ten grams of hydrochloric acid (HCl) act on zinc, and the same weight acts on calcium carbonate; what bulk of gas, measured at the normal temperature and pressure, is produced in each case? (12.)
3. Give the formulæ for three carbonates, three sulphates, three sulphites, and three nitrates. (9.)
4. How can you demonstrate that ammonia is composed of nitrogen and hydrogen? (10.)
5. Hydrogen is passed over red hot copper oxide (CuO), how much metallic copper is produced in forming 9 grams of water, and what is the volume of hydrogen at normal temperature and pressure which has been used? (15.)
6. How is sulphur dioxide made? How can you prove that it contains its own volume of oxygen? (10.)
7. Explain what is meant by chemical combination in definite and in multiple proportions. Give illustrations from carbon or sulphur compounds. (13.)
8. Both water and carbon dioxide are formed when coal gas burns; describe, and show by sketch, how you would prove this to be the case. (13.)
9. How would you prepare nitrous and nitric oxides? Give equations for the reactions, and state how you would recognise these bodies. (11.)
10. Three bottles are given you: in one is hydrochloric acid gas, in another chlorine, and in the third is ozone; by what properties and experiments would you recognise and identify each gas? (9.)
11. Describe how sulphuretted hydrogen is prepared. By what experiments would you show its properties and demonstrate its composition? (13.)
12. If air contains 21 per cent. by volume of oxygen, how many litres of it at standard temperature and pressure are required to burn completely 18 grams of carbon, and what would be the volume of the product formed? Weight of 11·2 litres of O = 16 grams. (13.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions.

$P = 31{\cdot}0. \quad Na = 23{\cdot}0.$

21. By what experiments would you show the principal properties of iodine? How would you distinguish a solution of potassium iodide from one of potassium bromide? (10.)

22. Distinguish between the atomic weight and the equivalent of an element. Give the formula of a nitrate, a sulphate, and a phosphate of a monad, diad, and a triad metal. (12.)

23. Three solutions are given to you: one contains sulphuric acid, another normal sodium sulphate, and the third acid sodium sulphate. How would you identify each? (11.)

24. Calculate the formula for a body which has the following percentage composition: oxygen, 38·1; hydrogen, 0·8; phosphorus, 24·6; sodium, 36·5. (12.)

25. Chlorine water exposed to light loses its colour. How do you account for this? (11.)

26. A solution of nitric acid of specific gravity 1·46 contains 80 per cent. of HNO_3. What weight of this solution is theoretically required to dissolve 10 grams of copper oxide? (15.)

27. Write the formulæ for the following ferrous and ferric salts: sulphate, phosphate, nitrate, chloride, and state by what general reactions the two classes of salts may be distinguished. What action has sulphuretted hydrogen on a solution of ferric chloride? (12.)

28. What combinations can be formed of arsenic with oxygen, with chlorine, with hydrogen? Describe the general properties of these bodies. (12.)

29. Give the formulæ, and describe the most important properties of the oxides of lead, copper, and mercury. (11.)

30. What are the chemical changes which occur when felspar is fused with sodium carbonate? (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions.

You must attempt questions 41 and 42. The remaining four you may select from any part of the paper. No class can be obtained in Honours unless questions 41 and 42 be satisfactorily answered.

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41. Describe the mode of determining a vapour-density by Hofmann's process. Calculate the vapour-density of carbon tetrachloride from the following data:—

Weight of liquid	0·3380 gram.
Vol. of vapour	109·8 cb.c.
Temperature	99·5°
Barometer	746·9 mm.
Height of column	283·4 „

(18.)

42. What experiments would you make in order to determine quantitatively the validity of the following equation:—

$$8NH_3 + 3Cl_2 = 6NH_4Cl + N_2. \qquad (18.)$$

43. What is the action of carbon dioxide on (*a*) ammonia gas, (*b*) an aqueous solution of ammonia. What is the composition of the ammonium carbonate of commerce? (17.)

44. Describe the methods adopted by Thomsen and Berthelot to determine the heat of neutralisation of acids. (16.)

45. What is the composition of white lead? How would you analyse it quantitatively? (13.)

46. Describe fully the modes used by Cailletet and Pictet to effect the liquefaction of oxygen. In what respects did their methods differ from those previously employed? (15.)

47. Nitrogen, which is usually regarded as a triad or a pentad, forms the oxides NO and NO_2; vanadium, which is a triad or a pentad, forms a di and a tetra chloride; uranium, which has hitherto been regarded as a tetrad or a hexad, forms a pentafluoride; tungsten, which is a hexad, also forms a pentafluoride. Discuss the bearing of these facts on the question of the classification of the elements in accordance with their valency. (16.)

48. Describe some of the more important methods for recovering sulphur from alkali waste. (14.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

Elementary Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.Sc.,
PH.D., F.R.S.

INSTRUCTION.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of your question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

1. You are required to prepare a solution of hydrochloric acid. What materials would you use? Explain your process and give a sketch of the apparatus you would employ. (10.)
2. A solution containing ammonium carbonate is given to you for analysis. State the tests by which you could recognise both the acid and base, giving equations in all cases. (10.)
3. How could you prove that on heating potassium chlorate, oxygen was evolved and potassium chloride was formed? (15.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC.,
PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the elementary stage examination is confined to the qualitative analysis of two simple salts, each containing not more than one acid and one base from the following list:

Lead, mercury, copper, bismuth, iron, calcium, barium, potassium, ammonium, carbonic acid, nitric acid, sulphuric acid, hydrochloric acid.

Two and a quarter hours are allowed for this part of the examination.

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

Advanced Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.Sc.,
PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

Whenever possible you are to express reactions in equations.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

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1. How could you distinguish between calomel and corrosive sublimate, and how could you obtain metallic mercury from each of these bodies? Give the formulæ of the two bodies. (10.)
2. Describe the action of a solution of ammonium sulphide upon solutions of the following bodies: Lead nitrate, calcium chloride, potassium alum, hydrochloric acid, zinc sulphate. Give equations. (10.)
3. A solution containing zinc chloride and calcium nitrate is given to you for analysis. Describe fully with equations how you would determine the presence of each acid and each base. (15.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC.,
PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Advanced Stage.

The two test substances supplied for qualitative analysis to candidates in the advanced stage consist of mixtures, each of which may consist of not more than two simple salts, the materials of which may be selected from the following list:—Potassium, sodium, ammonium, magnesium, calcium, strontium, barium, aluminium, chromium, zinc, manganese, iron, cobalt, nickel, arsenic, antimony, tin, cadmium, copper, bismuth, mercury, lead, silver, hydrosulphuric acid, hydrochloric acid, hydrobromic acid, hydriodic acid, sulphurous acid, nitric acid, chloric acid, carbonic acid, hydrofluoric acid, phosphoric acid, sulphuric acid.

Three and a quarter hours are allowed for this part of the examination.

Honours.

Three substances are supplied to each candidate in honours, two for qualitative and the third for quantitative analysis.

The two substances supplied for qualitative analysis consist of mixtures, which must be examined for all the bodies named above in the instructions for the advanced stage.

The substance for quantitative analysis need not be analysed qualitatively.

Quantitative Analysis.

Each candidate is furnished with a numbered bottle containing a powder in which ammonia has to be quantitatively determined.

The results must be expressed in grams of ammonia in 100 grams of the powder.

The candidate is recommended to weigh out, *accurately*, from 1 to 2 grams of the powder, for the purpose of analysis.

The candidate must not omit to place upon his worked paper the number attached to the bottle containing the powder he has analysed.

Eight honrs are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XI. · ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Whenever possible, you are to express the reactions by equations.

You are to give such numerical details as will show the mode of calculation.

The value attached to each question is indicated by a number placed at the end of the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions.

C=12 H=1 O=16.

1. What distinctions, if any, can be drawn between organic and inorganic substances? (9.)
2. Name the characteristic properties of an alcohol. (10.)
3. 0·333 gram of a non-nitrogenous body gave when burnt 0·4885 gram of carbon dioxide, and 0·2099 gram of water. Calculate its empirical formula. (13.)
4. Explain how you can convert carbonic acid into oxalic and formic acids. (12.)
5. How do chlorine and bromine act on the paraffins? (12.)
6. What action has sulphuric acid alone on alcohol, and what action has a mixture of sulphuric acid and potassium bichromate on alcohol? (12.)
7. How many times heavier is ether vapour than hydrogen? What weight of oxygen is necessary to burn completely 5 litres of ether vapour measured at the normal temperature and pressure? (14.)
8. What do you understand by the term "compound radical"? Name the compound radicals which are assumed to be contained in wood-spirit, spirits of wine, chloroform, and acetic acid. (13.)
9. How can carbonic oxide be obtained from formic and from oxalic acids? Describe the principal properties of carbonic oxide. (12.)
10. What evidence can be adduced that chlorine is a constituent of chloroform? (9.)
11. Explain and illustrate the analogy between cyanogen and chlorine. (12.)
12. How can you obtain the alcohol from a mixture of alcohol and water? (12.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *eight* questions.

C=12 H=1 O=16 P=31.

21. Give the constitutional formula of acetic acid and state the evidence upon which this formula is based. (11.)

22. Indicate the relationship existing between succinic, tartaric, and malic acids. How can malic acid be converted into succinic acid and succinic acid into malic acid? (14.)

23. How is glycerin obtained? What is the evidence that it is a trihydric alcohol? How may it be converted into oxalic acid? (15.)

24. What are the chief characteristics of the different kinds of sugars? By what reactions could you distinguish between grape-sugar and cane-sugar? (10.)

25. Describe Dumas' method of determining the vapour-density of a body. (10.)

26. From what plants are morphine, strychnine, and quinine extracted? What are the general properties of these bodies and in what respects do they resemble ammonia? (15.)

27. Describe the chemical changes which occur when cane-sugar is converted into alcohol by fermentation. How can alcohol be converted into acetic acid? (12.)

28. How is triethylphosphine prepared? Describe its properties and calculate its percentage composition. (13.)

29. How can urea be artificially prepared? How can you show that it contains nitrogen? Why is it sometimes called carbamide? (12.)

30. Describe the successive steps by which aniline is prepared from benzene. (10.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt six* questions.

You must attempt questions 41 and 47.

The remaining four you may select from any part of the paper. No class can be obtained in Honours unless questions 41 and 47 be satisfactorily answered.

41. Give a short account of the theories which have been proposed concerning the constitution of benzene. (16.)
42. Describe how you would determine the molecular weights of strychnine, nicotine, and glycerine. (13.)
43. Give some account of the researches of Fischer on the relations of caffeine to uric acid. (18.)
44. What is the chemical nature of gun-cotton? How can it be reconverted into cellulose? How could you determine its elementary composition? (15.)
45. How could you ascertain by physical methods the composition of a mixture of ethyl alcohol and fermentation amyl alcohol? (14.)
46. Every organic compound whose solution rotates a ray of polarized light contains one or more asymmetric atoms of carbon. Discuss this statement and explain its application to the theory of isomerism. (18.)
47. What are the proximate constituents of bread, milk, butter and blood? Give their characteristic properties, and describe how you could isolate them. (16.)
48. A mixture of ethyl iodide, carbon disulphide, and acetic acid is given to you for analysis. Describe how you could separate and determine the amount of each ingredient. (16.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You must take the same stage in this written examination that you are taking in the examination in Practical Analysis in this subject.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *two* questions.

1. How could you ascertain that vinegar contains acetic acid? (10.)
2. Describe, with a sketch, how ether is made. (10.)
3. Give the tests by which you would distinguish between oxalic and tartaric acids. (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *two* questions.

21. Describe the various methods of preparing marsh gas, and give sketches of the apparatus employed. How could you distinguish this gas from hydrogen and from ethylene? (15.)
22. Describe the method of making an elementary organic analysis of sugar. (10.)
23. How could you obtain oxalic acid from sugar? What is the action of a solution of ammonium oxalate upon the following bodies: lead acetate, sulphuric acid, calcium chloride, ferrous sulphate? (10.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the Elementary Stage Examination is confined to the qualitative analysis of two mixtures, which may each contain not more than two of the following constituents, together with an inorganic base or bases which need not be determined:—

Formic acid, acetic acid, oxalic acid, tartaric acid, salicylic acid.

Two and a quarter hours are allowed for this part of the examination.

Advanced Stage.

The practical work for the advanced stage examination is confined to the qualitative analysis of two substances, each of which may contain not more than two simple organic salts; the materials will be selected from the following list, together with one or two inorganic bases, which are also to be determined: Hydrocyanic acid, formic acid, oxalic acid, acetic acid, benzoic acid, succinic acid, tartaric acid, citric acid, and salicylic acid.

Three and a quarter hours are allowed for this part of the examination.

Honours.

The examination in Honours consists of a qualitative analysis of the two mixtures supplied, and of the determination of the percentage of carbon and hydrogen contained in the organic substance distributed for this purpose.

The bottle marked (A) contains a substance in which the percentage of carbon, hydrogen, and oxygen (the latter by loss) is to be determined by Organic Analysis.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XII. GEOLOGY.

EXAMINER, H. W. BRISTOW, F.R.S., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are only permitted to *attempt eight* questions.

You *must attempt* the *first three* questions on the paper. The remaining *five* you may select from any part of the paper.

The value attached to each question is the same.

1. Explain the meaning of the term Tertiary, as used in Geology.
2. Describe an *Ammonite.* In what rocks do Ammonites occur?
3. Briefly describe the minerals which go to form *Granite* or *Basalt.*

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4. Define the terms Synclinal, Outcrop, Dyke, Breccia.
5. What is Sandstone? How has it been formed?
6. Arrange in vertical order the following Formations according to their relative ages, placing the oldest at the bottom of the list:—Llandeilo Beds, Forest Marble, Devonian Beds, Upper Greensand, Lingula Flags, London Clay, Oxford Clay.
7. How may it be inferred that certain rocks were formed in shallow water?
8. What are "submerged forests"? How have they been formed?
9. Explain the difference between Pebbles and Nodules.
10. Describe briefly the rocks known as Old Red Sandstone. Where do they occur, and what is there specially interesting as to their fossils?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are only permitted to *attempt six* questions.

You *must attempt* the *first two* questions on the paper. The remaining *four* you may select from any part of the paper.

The value attached to each question is the same.

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21. Clays are of various shades of blue, brown, or red, &c. To what are these differences of colour usually due?
22. Draw an imaginary section across a tract of country, showing *springs* produced in four different ways.

23. Describe three important kinds of rock mainly or entirely composed of Carbonate of Lime; and give the geological ages of each of the kinds you mention.

24. Give the names of six species of Ammonites which are especially characteristic of definite horizons in the Jurassic series, giving the exact geological horizon of each.

25. What are Concretions? How have they been formed?
Describe some that are of economic value, occurring in the British Isles.

26. Compare the marine Fauna of the Silurian, Liassic, and Eocene periods.

27. What is implied by the term Oligocene? In what part of the British Isles do beds occur which are referred to this age?

28. Describe the mode of occurrence of the ore from which Silver is procured in Britain. Mention the districts and the rocks in which it is found.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are permitted to *attempt all* the questions.

The value attached to each question is the same.

41. The approximate geological age of rocks is inferred from the fossils which they contain.
Describe some case in which the evidence afforded by Plants seems not to agree with that afforded by the Mollusca.

42. Describe the salient characters of the Deinosauria, mentioning the chief forms and their geological range.

43. What is the evidence for the Glaciation of Britain?
Distinguish between the evidence afforded in West Yorkshire and in Norfolk?

44. Compare the Lias of South Wales, Dorset, and Yorkshire.

45. In what British Formations do *lacustrine* or *estuarine* deposits occur?
State the reasons for referring such deposits to one or other of those modes of deposition.

46. Describe the rocks in Britain which are classed as Archæan.
Give your reasons for such classification in each example which you mention.

SUBJECT XIII. MINERALOGY.

EXAMINER, F. RUTLEY, ESQ.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt six* questions in all, of which the last question (No. 10) is obligatory.

The value attached to each question is shown in brackets after the question.

1. Give the chemical composition of the following minerals:—Calcite, quartz, barytes, fluor-spar. (14.)
2. In what systems do these minerals respectively crystallise? (14.)
3. What are the directions of cleavage in calcite and fluor-spar? (14.)
4. By what simple tests may calcite, quartz, barytes, and fluor-spar be respectively recognised? (14.)
5. Describe the minerals hematite and corundum, mentioning any varieties and the uses to which they are applied. (14.)
6. Give Mohs' Scale of Hardness and state in what systems Nos. 8, 9, and 10 of that scale respectively crystallise. (14.)
7. State what you know concerning rock-salt and its mode of occurrence. (14.)

8. Name any mineral which crystallises in the form of a rhombic dodecahedron. To what system does this form belong, how many faces does it present, and what is the form of each face? (14.)

9. Name any minerals which exhibit phosphorescence, Under what conditions is this phenomenon displayed? (14.)

10. Name the three specimens placed before you, giving the systems in which they respectively crystallise and the chemical composition of each. Also make a blowpipe examination of the three powdered minerals given you, stating your results, and the means by which you have arrived at them. (30.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions in all, of which the last two (Nos. 29 and 30) are obligatory.

The value attached to each question is shown in brackets after the question.

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21. What is an optic axis? Give two examples of uniaxial and two of biaxial crystals. (14.)

22. By what means do you distinguish a uniaxial from a biaxial crystal? (14.)

23. What is the chemical composition of albite? In what system does it crystallise and in what directions is it cleavable? (14.)

24. Describe the minerals zircon and beryl. (14.)

25. By what characters would you distinguish muscovite from biotite and barytes from celestine? (14.)

26. In what systems do the following minerals crystallise:— Natrolite, epidote, brookite, augite, and pyrargyrite? (14.)

27. How would you distinguish spinel from ruby, both stones being cut and polished, and of approximately the same colour? (14.)

28. Draw a crystal of selenite, marking the different faces with Miller's or Naumann's symbols and define the position of the optic-axial plane. (14.)

29. Describe the six models placed before you, naming a mineral which crystallises in each of these forms. (14.)

30. Name the three specimens placed before you, giving the chemical composition and crystallographic system of each. Also make a blowpipe-analysis of the three powdered minerals supplied to you, briefly describing your mode of procedure and the qualitative results. (30.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions in all, of which the last (No. 48) is obligatory.

The value attached to each question is shown in brackets after the question.

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41. Name three minerals having the general formula RSO_4, and describe one of them. (14.)

42. Describe the section of the wave-surface of a biaxial crystal in the plane of the axes of maximum and mean elasticity, and illustrate your description by a drawing. (14.)

43. Describe the minerals, pyrites, cobalt-glance and marcasite. (14.)

44. How would you distinguish a positive from a negative uniaxial crystal? (14.)

45. Describe the phenomena usually presented by the interference-figures of rhombic and monoclinic crystals. (14.)

46. To what groups do the minerals anthophyllite, enstatite, and zoisite respectively belong, and what characters have these species in common? (14.)

47. Draw a twinned crystal of staurolite, marking the faces with Miller's symbols. Give also Naumann's symbols for the forms represented in your drawing. (14.)

48. Name the six specimens placed before you, giving the chemical composition of each, and the system in which it crystallises. Make, also, a complete qualitative blowpipe analysis of the three powdered minerals set before you, describing the results of your analysis and the processes by which you have arrived at those results. (30.)

SUBJECT XIV. ANIMAL PHYSIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR M. FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

The Examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions. You must *attempt* the first *four* questions on the paper; the remaining four you may select from any part of the paper.

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1. About how much air do we take into the chest at a breath? What makes it go in? What makes it come out? What is the effect on the lungs of trying to take a deep breath, if, while trying to take it, we keep the nose and mouth tightly closed? (16.)

2. What is the composition of fat, and how does it differ from that of sugar? What is meant by the digestion of fat? Where and how does it take place? (16.)

3. Of what parts is the wrist joint made up? How do the movements of the hand which you can make at the wrist joint differ from those of the foot which you can make at the ankle joint, and why? (16.)
4. How, in a living body, does the blood flow from a cut artery, and how from a cut vein? Why is the flow different in the two cases? How can you best stop the bleeding from a cut artery, and how from a cut vein? (16.)

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5. What is a muscular fibre? About how big is a muscular fibre of one of your own muscles? Explain how muscular fibres are built up into an ordinary muscle. (9.)
6. How does the arrangement of the blood-vessels and the circulation of the blood in the liver differ from the arrangement of the blood-vessels and the circulation of the blood in a muscle? What purpose is served by the peculiar blood supply of the liver? (9.)
7. Where is the spinal cord placed? Where and how does it end above and below? What can you learn concerning its structure without using a microscope? (9.)
8. How does the upper part of the cavity of the nose into which the nostril leads differ from the lower part? What different functions are performed by the two parts? (9.)
9. Of what two distinct parts is the skin made up? How do they differ from each other in structure, and what are the chief uses of each part? (9.)
10. What is saliva? Where and how is it formed? What are its uses? (9.)
11. Explain how it comes about that your body has about the same temperature on the hottest day in summer and the coldest day in winter. What is that temperature? (9.
12. When a body has been buried for some time, nothing is left but the bones. Why have all the other parts disappeared, and what has become of them? (9.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions. You must *attempt* the first *two* questions on the paper; the remaining three you may select from any part of the paper.

21. Describe the structure of an artery as made out (*a*) without the help of, (*b*) with the help of, a microscope. What are the two chief properties of the arteries in the living body? How do large and small arteries differ in regard to these properties? What part do these properties respectively play in carrying on the circulation of the blood? (26.)

22. Give an account of the structure of the lung, pointing out the uses of the several parts in carrying on the work of respiration. State exactly, and explain fully, what happens to a lung when a free opening is made into its pleural cavity through the chest walls, and what are the results of the respiratory movements under those circumstances? (26.)

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23. Describe the structure of a villus in the small intestine. State how a villus differs in appearance and condition according as food has or has not been taken, and explain the part played by a villus in absorbing digested food. (16.)

24. What is lymph? What is the ultimate source of lymph? What determines its greater or less abundance in a tissue from time to time? In what parts of a tissue is it lodged before it finds its way into the minute lymphatic vessels, and what are the causes which lead to its flowing onward along the lymphatic vessels into the venous system? (16.)

25. Describe the structure of the spleen. What changes take place in the size of the spleen from time to time, and how are those changes brought about? (16.)

26. Give an account of the vagus, or pneumo-gastric nerve, stating from what part of the brain it takes its origin, and to what parts it is distributed. State in the order of their importance the chief functions of this nerve. (16.)

27. Give an account of the appearance, structure, and relations of the *chordæ vocales*. Describe the changes which take place in the larynx, (*a*) when a high note, (*b*) when a low note is sounded, and explain how those changes are brought about. (16.)

28. Describe the structure of the iris. Under what circumstances is the pupil widened, under what circumstances narrowed? Explain the nervous agency by which the widening and the narrowing are brought about. (16.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions. You must *attempt* the first *two* questions on the paper; the remaining two you may select from any part of the paper.

The value attached to each question is the same.

41. Describe the minute structure of the iris. State the several events which lead respectively to narrowing and widening of the pupil, and explain, as far as our present knowledge permits, how these are brought about, pointing out the nervous paths and centres concerned, and discussing the nature of the local mechanisms.

42. Describe the origin of lymphatic vessels, and discuss the various causes which determine the quantity and quality of the lymph present in any part of the body—in a limb, for instance—and the rapidity with which it is removed or renewed.

43. Describe accurately the sounds of the heart, including the modifications which may occur in them, and discuss fully their nature and causes.

44. Describe the structure of a typical nucleus, its relation to the cell-substance, and the changes which it undergoes during cell division. State and criticise the evidence which has been adduced in favour of the view that the nucleus exerts an influence on the changes which take place in the cell-substance of the cell to which it belongs.

45. Give an account of the several parts played by the vagus nerve in the general working of the animal body, as seen in health and disease, distinguishing the constituent parts of the trunk of the vagus, commonly so called.

46. Explain what is meant by "tissue proteid" and "circulating proteid," stating, and defending or criticising, the reasoning on which such a distinction is made.

Practical Examination.

1. Describe *one* of the specimens A, B, C, stating the histological points which it illustrates.
2. Stain and mount one of the cut sections D and state its nature.
3. Examine the fluid E and say what you consider it to be.
4. Demonstrate by the graphic method the nature of the curve of a tetanic contraction.

SUBJECT XV. BOTANY.

EXAMINERS.—S. H. VINES, ESQ., M.A., D.Sc., F.R.S., and
D. H. SCOTT, M.A., Ph.D.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced stages is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The Examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *six* questions.

You must *attempt* the first *two* questions on the paper. The remaining four you may select from any part of the paper.

1. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem,	Calyx,	Pistil,	
Leaves,	Corolla,	Fruit,	
Bracts,	Stamens,	Seed.	(24.)

2. From what source does a green plant obtain its carbonaceous food, and in what form and by what organs does it absorb it? What are the conditions upon which the assimilation of the carbonaceous food depends? (20.)

3. Compare the structure of the root of any flowering plant with that of its stem. Mention and briefly describe cases in which (*a*) the stem, and (*b*) the root has become modified to serve as a depository of reserve materials. (14.)

4. Describe in detail the structure of an anther and of a pollen-grain. (14.)
5. State what is meant by annual, biennial, and perennial plants, giving examples. (14.)
6. Describe, with examples, the structure of (*a*) a hypogynous, (*b*) a perigynous, and (*c*) an epigynous flower. (14.)
7. Describe, with diagrams, the primitive structure and the mode of growth in thickness of the stem of a dicotyledonous plant. Why does the stem of dicotyledonous plants usually increase in thickness? (14.)
8. Describe the method by which the importance of the various mineral constituents of a plant's food has been most satisfactorily ascertained. (14.)
9. Describe and compare the seeds of the Bean and of the Wheat. (14.)
10. Briefly describe, giving examples, the following forms of inflorescence, and point out the relation which exists between them: spike, spadix, raceme, head. (14.)
11. State what is the tissue in which water travels from the root to the leaves, mentioning illustrative experiments. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *six* questions.

You must *attempt* the first *three* questions on the paper, the remaining three you may select from any part of the paper.

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21. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem, Calyx, Pistil,
Leaves, Corolla, Fruit,
Bracts, Stamens, Seed. (24.)

22. Describe the structure of a growing cell, and state what are the conditions which are essential to growth. (17.)
23. Draw the floral diagram of any grass, and state in what respects it differs from that typical of the petaloid monocotyledons. (17.)

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24. Describe the structure of a vascular bundle in the stem of any monocotyledon, and state in what order the different parts are developed. (14.)

25. Describe the aril of any British plant. (14.)

26. Describe the structure, and state what are the functions, of root-hairs. By what means is a root able to absorb from the soil substances which are insoluble in water? (14.)

27. State what are the general characteristics of the epidermal tissue of the sub-aërial parts of plants. (14.)

28. Give an account of the structure, the mode of growth, and the chemical composition of a starch-grain. (14.)

29. Briefly describe the peculiarities occurring in the various British genera of Ranunculaceæ, in (*a*) the structure of the flower, and (*b*) the structure of the fruit. (14.)

30. Describe the process of cell-formation in (*a*) the vegetative tissues, and (*b*) the endosperm, of a flowering plant. (14.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

You must *attempt* the *first* question on the paper, the remaining *four* you may select from any part of the paper.

The value attached to each question is the same.

41. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem,
Leaves,
Bracts,
Calyx,
Corolla,
Stamens,
Pistil,
Fruit,
Seed.

42. Describe the vernation of the fronds of a fern. Explain how this form of vernation is produced, and the mode in which the expansion of the frond takes place.

43. Describe fully the structure and development of the sieve-tubes, and discuss their probable function.

44. Briefly discuss the various means by which the self-fertilisation of flowers is prevented.

45. Describe and compare the structure, at the time of fertilisation, of the ovule of a gymnosperm and of an angiosperm. Describe minutely the process of fertilisation.

46. Mention those monocotyledons the stem of which grows in thickness. Point out how the mode of growth in thickness of these stems differs from that which obtains in the stem of dicotyledons.

47. A bean-seed contains starch and albuminoids: the seedling produced on germination contains largely sugar and asparagin. What is the nature of the chemical changes which have taken place, and by what means have they been effected?

48. Give an account of the Flora of the Azores. Assuming that the Azores are oceanic islands, how is the facies of the Flora to be accounted for?

Practical Examination.

(*Botany and Vegetable Morphology and Physiology.*)

FIRST PAPER. 3 hours, 10—1.

1. Make a preparation to show the *young* embryo of *Capsella*. The stage shown must be one *before* the appearance of the cotyledons.

2. Make a longitudinal section of the ovule of *Pinus* to show the archegonia.

3. Make a transverse section of a *lateral branch* of the plant provided, to show the anatomical structure. (*Ruscus aculeatus*).

   One preparation only must be shown in each case, and must be left in the field of the microscope. Each preparation must be *drawn* and *described*.

SECOND PAPER. 2 hours, 2—4.

1. Identify and describe the specimens marked *A* and *B*. Fifteen minutes allowed each student for each specimen.

   [Specimen *A*. Preparation of stem of *Catakidozamia*.
   „ *B*. Preparation of stem of *Yucca*.]

2. Identify and describe the six microscopical preparations marked *C* to *H*.

   The preparations must ON NO ACCOUNT be shifted.
   Fifteen minutes allowed each student for each preparation.

   [Specimen *C*. Laticiferous cells of *Jatropha*.
   „ *D*. Section of leaf of *Chamærops*.
   „ *E*. Section (transverse) of root of *Angiopteris*.
   „ *F*. Section („) of leaf of *Pinus*.
   „ *G*. Section („) of root of *Taxus*.
   „ *H*. Section („) of stem of *Psilotum*.]

SUBJECTS XVI. AND XVII. GENERAL BIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR MICHAEL FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS..

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Elementary paper;

Or from the Advanced paper in Animal Morphology and Physiology;

Or from the Advanced paper in Vegetable Morphology and Physiology;

Or from the Honours paper in Animal Morphology and Physiology;

Or from the Honours paper in Vegetable Morphology and Physiology;

But you must confine yourself to one of them.

Where the values differ, that attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will, in all cases, secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in these subjects lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

You must *attempt* the first *four* questions on the paper. The remaining four you may select from any part of the paper.

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1. What do Brewers add to "wort" in order to make beer? What is the nature of the substance added? What changes does it bring about in the wort, and why, when fermentation is over, is there a great deal more of the substance than was put into the wort? (16.)

2. Of what parts is a common pea or broad bean, such as is cooked and eaten, made up? What was the early state of such a pea or bean at the time when the pea-flower or bean-flower which bore it had just opened, and by what changes did it become what it is? (16.)

3. What is the structure of a Bell-animalcule or Vorticella? How does it move, and how does it get and eat its food? How does it differ from a freshwater polype? (16.)

4. When does a mussel keep his shell gaping open, and when does he shut it? How does he open it, and how does he shut it? (16.)

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5. The underground creeping part of the bracken fern is often called by some people a *root*. Is this right? If not, why? What ought it to be called? (9.)

6. What is the structure of a sea anemone. How does it resemble, and how does it differ from a freshwater polype? (9.)

7. How does a coloured petal (like that of a tulip, for example) resemble and differ from a leaf? What is it which the leaf can do and the petal cannot, and why? What is it the petal does which the leaf does not, and why? (9.)

8. Explain how a frog breathes. Can a frog breathe without his lungs? If so, how? (9.)

9. If you cut off a branch from a tree or shrub in summer the leaves soon become flabby. Why is this? If you put the cut end of the branch in water the leaves often become quite fresh and plump again. Why is this? (9.)

10. State fully and exactly the various reasons why the body of a frog is considered to be made up of a number of segments. (9.)

11. Where is the auditory organ or ear of the crayfish placed? What is its structure? How is it supposed to act? (9.)

12. How does a tadpole resemble and differ from a frog? State briefly the changes by which a tadpole becomes a frog. (9.)

SUBJECT XVI. ANIMAL MORPHOLOGY AND PHYSIOLOGY.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

You must *attempt* the first *two* questions on the paper. The remaining three you may select from any part of the paper.

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21. What are the essential characteristics of a sacral vertebra? Mention an animal belonging to each of the following categories—(*a*) with no sacrum; (*b*) with one sacral vertebra; (*c*) with two sacral vertebræ; (*d*) with a "sacrum" consisting of more than two vertebræ, by addition of caudal vertebræ; and (*e*) by addition of lumbar as well as caudal vertebræ. (26.)

22. What are the chief resemblances and differences observable between a cuttle-fish and a common slug? (26.)

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23. How is the cerebro-spinal nervous system of a vertebrated animal developed? (16.)

24. What are the *Turbellaria*? With what other groups of animals are they most closely allied? (16.)

25. Describe the jaws, mouth, and alimentary canal of a spider. In what respects do the corresponding parts of scorpions differ? (16.)

26. In what respects do the larval forms of many Annelids, Mollusks, and Echinoderms resemble one another and the *Rotifera*? What is the ordinary course of metamorphosis in a marine annelid larva? (16.)

27. How are the *Amphibia* distinguished from *Pisces* and *Reptilia?* (16.)

28. What are the most interesting peculiarities of the *Salpæ?* (16.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

You must *attempt* the first *two* questions on the paper, the remaining two you may select from any part of the paper.

The value attached to each question is the same.

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41. Give an account of the structure and development of *Peripatus*, and discuss its affinities.

42. Describe the bones of the pectoral and pelvic arches, and of the corresponding limbs in such a bird as a pigeon; and compare them with those of (*a*) a young ostrich, (*b*) a penguin, (*c*) a pterodactyl, (*d*) a bat.

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43. What are the modes in which the air-bladder is connected with the organ of hearing in the *Cyprinidæ* on the one hand, and in the common herring on the other?

44. What are the distinctive characters of the *Crocodilia?* How are they distributed geographically? What is their geological range? How do the older forms differ in structure and habitat from the more modern crocodiles?

45. Give an account of the *Brachiopoda;* and discuss the question whether they have closer affinities with the Annelids than are exhibited by Lamillibranchs, Gasteropods, and Pteropods.

46. Give an account of the organisation and metamorphoses of any Dipterous insect. What is there peculiar about the process of metamorphosis in certain *Diptera?*

SUBJECT XVII. VEGETABLE MORPHOLOGY AND PHYSIOLOGY.

EXAMINERS, S. H. VINES, ESQ., M.A., D.Sc., F.R.S., AND
D. H. SCOTT, ESQ., M.A., PH.D.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

You must *attempt* the first *two* questions on the paper. The remaining three you may select from any part of the paper.

51. Give an account of the process of Respiration in plants, stating the ways in which it may be affected by external conditions. What is the nature of the metabolic processes of which Respiration is the expression? (23.)

52. Trace the life-history of any Liverwort, and compare it with that of a Fern. (23.)

53. Describe fully the typical structure of a foliage-leaf, and point out the relations which exist between the structure and functions of the leaf. (18.)

54. Describe the process of fertilisation in a Flowering-Plant, and compare it with that in a Vascular Cryptogam. (18.)

55. Describe the structure and reproduction of *Saprolegnia*. Compare the sexual organs of *Saprolegnia* with those of *Mucor*. (18.)

56. Give an account of the process of absorption of water by roots, and explain how the root-pressure is set up. (18.)

57. Give an account of the structure, reproduction, and development of *Fucus*. (18.)

58. Give an account of the forms in which nitrogenous reserve-materials are stored up in seeds, and state what is the chemical nature of these materials (18.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

You must *attempt* the first *two* questions on the paper, the remaining two you may select from any part of the paper.

The value attached to each question is the same.

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61. What is Transpiration, and what is its significance in the economy of the plant? Discuss the various recent theories as to the mode in which the water of the transpiration-current travels in the wood.

62. What is the *Archesporium?* Compare its development in Polypodium, Selaginella, Pinus, and the Angiosperms.

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63. Give an account of the various modes of development of the embryo from the oospore in Gymnosperms.

64. State what are the differences between an etiolated and a normal plant of the same kind, and give an explanation of these differences.

65. Classify, giving examples, the modes of sexual reproduction observed in the Fungi.

66. Give instances of the conduction of a stimulus in plants and explain by what means the conduction is effected.

(*N.B.—The questions set at the Practical Examination in this subject will be found at p.* 104.)

SUBJECT XVIII. PRINCIPLES OF MINING.

EXAMINER, H. BAUERMAN, ESQ., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The Examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

1. What are the general characters of the deposits in which the following minerals are found?
   (*a*) Coal.
   (*b*) Salt.
   (*c*) Tin ore.

2. What is the method usually adopted for finding the continuation of a coal seam that has been broken by a fault?

   Describe, with sketches, the kinds of picks used for working in stone and coal respectively.

4. How would you sharpen and temper the bit of borer for boring by hand in rock? What shape and dimensions would you prefer?

5. What is the construction of safety fuse, and how is it used with gunpowder and dynamite respectively?

6. How is water raised from a deep mine without pumps?

7. What dangerous and deleterious gases are likely to be met with in working coal or metal mines respectively?

8. What volume of fresh air should be provided per minute in a colliery for each man employed underground?

9. What methods are generally adopted for ventilating the ends of workings in mines?

   Give some examples, with sketches, either from coal or metal mines.

10. Describe the operations of getting coal in a long wall working, with illustrations.

11. Give an account with some illustrative details of—
    (*a*) A vertical shaft with wire-rope guides for cages; or
    (*b*) An inclined shaft with a skip road.

12. What is the construction of the plunger jigging machine, and how is it applied in the dressing either of coal or metallic ores?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

21. What is meant by the expression: *a true fissure vein*, and how does such a vein differ from other kinds? Give some examples.

22. What interruptions are likely to be met with in working coal seams, and how should mines be laid out with reference to such interruptions?

23. Describe, with sketches, the method of timbering a large level in which horse traction is to be used. How can wrought iron be used instead of timber for securing such a level?

24. Describe the method of underground haulage by the endless chain system, with details of the construction of the roadway and waggons.

25. What observations are required in order to determine the mechanical efficiency of the method employed in ventilating a mine.

26. How may the workings on a large mineral vein be secured without timber?

27. What is the effect of fire-damp upon the flame of a safety lamp, and what other methods of testing the air of mines for inflammable gas have been proposed?

28. What are the principal methods in use of signalling from the bottom of a deep mine to the surface, and of indicating the position of the cage or skip in the shaft?

29. How are the surveys of mines made and plotted?

30. Describe the lime-cartridge method of breaking down coal.

31. How is compressed air obtained for use underground?

32. Describe the process of dressing tin-stuff for black tin.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions.

These you may select from any part of the paper.

The value attached to each question is the same.

41. Give an account of the North Staffordshire coalfield.
42. Give an account of the principal European lead mining districts.
43. Describe a method of putting down a shaft through a quicksand without the use of pumps.
44. Describe two forms of centrifugal ventilators suitable for collieries, giving details of construction and of their mechanical efficiency.
45. How has electricity been applied to underground haulage?
46. Describe the construction of a pumping engine driven by the pressure of a column of water.
47. Give an account of the plant and machinery required for driving a pair of rock drills by compressed air at a considerable distance from the source of power.
48. Describe and discuss the principal machines used for grinding minerals before or during the processes of dressing.

SUBJECT XIX. METALLURGY.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question and of the section before your answer.

You are to confine your answers *strictly* to the questions proposed; answers extending beyond the scope of the questions are disregarded by the Examiner.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not to *attempt* more than *six* questions in this paper.

The value attached to each question is the same.

For a pass in the Elementary stage the student will only be expected to answer questions in *two* of the following *four* sections. At least two questions must, however, be taken from Section I.

For a FIRST CLASS in the Elementary stage the candidate must answer questions in *three* sections. At least two questions must be taken from Section I.

SECTION I.

1. What is the effect of "rolling" and of "wire-drawing" on the density of metals?
2. Give an instance in which one metal may be separated from another by crystallization.
3. What materials containing much silica are used to resist high temperatures in metallurgical appliances?
4. Draw a vertical section of an ordinary beehive coke oven, or of any coke oven you may have seen in use.

SECTION II.

5. Iron ore, coke, and flux, are charged into the top of a blast furnace, and pig-iron is tapped out from the base of the furnace. Explain how the carbon acts on the ore so as to render this result possible.
6. Describe the physical properties of "pig-iron," "malleable iron," and "steel," and show to what industrial uses each of them is specially applicable.
7. Describe the operation of puddling, and state how it removes carbon from pig-iron.
8. State why at the conclusion of the "blow" in the Bessemer process, Spiegeleisen is added.

SECTION III.

9. How would you extract, by a furnace method, the precious metal from quartz containing gold?

10. An alloy contains 20 per cent. of gold and 80 per cent. of silver. How would you separate the two metals?

11. What is the action of chlorine gas on melted gold, and on melted silver respectively?

12. How would you remove silver from mercury? Show by a sketch the apparatus you would use.

SECTION IV.

13. In smelting impure lead ores by the Cornish process, iron is added; what is its action?

14. What use is made of oxidized ores in the Welsh process of copper smelting?

15. State the compositions of the principal ores of copper.

16. What reactions take place when oxide of copper is strongly heated with sulphide of iron and silica?

17. Describe the Belgian process for the extraction of zinc from its ores.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to *attempt* more than *six* questions in this paper.

The value attached to each question is the same.

For a pass in this stage the student will only be expected to answer questions in *two* of the following *four* sections; at least *two* questions must, however, be taken from Section I.

For a FIRST CLASS in this stage the candidate must answer questions in *three* sections; at least *two* questions must be taken from Section I.

SECTION I.

21. Give four instances of the influence of small quantities of impurity on the physical properties of metals.

22. Explain fully the action of carbon in the reduction of oxides of metals to the metallic state.

23. What substances would you add to fluxes with a view to increase the fusibility of slags?

24. Name the six specimens submitted to you.

SECTION II.

25. The oxides of iron of metallurgical importance are ferrous oxide (FeO), ferric oxide (Fe_2O_3), and magnetic oxide (Fe_3O_4). State what you know concerning their respective uses.

26. The waste gases from a blast furnace used for smelting iron are combustible; account for this.

27. The presence of manganese in an iron ore is advantageous. What are the reasons for this fact?

28. Distinguish between "white," "grey," and "mottled" pig-iron. Why is "white" pig-iron more suitable for the dry puddling process than the "grey" pig-iron.

SECTION III.

29. How would you remove the silver from an electro-plated article, so as to recover the precious metal?

30. Describe any method for toughening brittle gold.

31. How would you reduce chloride of silver to the metallic state?

32. Describe fully the method of preparing chemically pure gold.

SECTION IV.

33. How would you obtain a fusible slag when smelting, in the blast furnace, lead and copper ores rich in zinc?

34. How would you convert "coarse metal" into "white metal" in the Welsh method of copper smelting? Describe the method of refining copper, and give a sketch of the furnace.

35. Lead after desilverisation by the aid of zinc still retains some of this metal. How would you propose to remove the zinc?

36. A tin ore is found to contain Wolfram. What alteration in the ordinary process for smelting the ores would its presence render necessary?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to *attempt* more than *eight* questions, and in these No. 51 must be included.

The value attached to each question is the same.

40. Give a general classification of fuels based on the amount of "free" or "disposable" hydrogen they contain, and state what would probably be the distinguishing characteristics of a fuel having the following constituents:—

Carbon	82·5
Hydrogen	5·4
Oxygen and Nitrogen	12·1
	100·0

Calculate its calorific value.

41. Under what circumstances as regards fuel, labour, and fire-resisting materials, would you employ respectively the blast furnace and reverberatory methods of treatment in the case either of lead ores, or of copper ores?

42. Lead produced from mixed ores is found to contain antimony, tin, copper, and iron. Describe the process of purification, and state at what stages these different metals are eliminated.

43. What methods may be adopted for treating the "scum" which rises to the surface of a bath of lead after the dezincification of the metal by the Cordurié process?

44. The "tailings" from pan amalgamators are found to be rich in the precious metals. How would you treat these "tailings"?

45. How would you extract gold and antimony from an auriferous stibnite?

46. In what manner would you treat a speise of copper, nickel, and cobalt, with a view to extract these metals?

47. The copper ores of the Mediterranean coasts are frequently accompanied by considerable quantities of arsenical compounds. How would you treat such ores?

48. Ingot iron produced by the Bessemer process contains "blow holes." In what portion of the ingot are these most abundant? How do you account for their presence, and by what means can their formation be avoided?

49. Distinguish between the nature of the charge, and the temperature and pressure of the blast, when iron ore is smelted with a view to the production of "white" or "grey" pig-iron respectively.

50. Describe, with the aid of sketches, the arrangements recently proposed for distributing the gas and air in a Siemens' regenerative furnace.

51. Name and describe briefly the six specimens submitted to you,

SUBJECT XIX*p*. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Elementary Stage.

Three hours are allowed for this examination.

1. The candidate is required to form, by a dry process, sulphide of lead from some of the sulphur and lead given to him. He must describe the physical character of the product he obtains, and deduce its chemical composition from the increase in weight of the lead used.

2. The sample is oxide of copper, a portion of which the candidate is required to reduce to the metallic state by charcoal powder.

   Note.—The candidate must place the number of his examination paper on the products he obtains, and hand them to the Superintendents of the examination, to be returned to the Department for examination.

SUBJECT XIX$_p$. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Advanced Stage.

Four hours are allowed for this examination.

1. The candidate is required to describe the ore of mercury given to him, and he is to determine, experimentally, the percentage of mercury it contains.
2. The candidate is required to reduce oxide of copper by sulphide of copper. He is to ascertain the nature of the materials supplied to him for this purpose, and he is to state what reaction takes place in conducting the operation.

   Note.—The candidate must place the number of his examination paper on the product he obtains in the *second question*, and hand it to the Superintendents of the examination, to be returned to the Department for examination.

Honours.

Eight hours are allowed for this examination.

1. The sample is pig iron; the candidate is required to determine the amount of silicon and graphite it contains. He is to describe briefly the method used.
2. The sample is a variety of brass; the candidate is required to determine the amounts of zinc and of lead present. He is to describe briefly the method he employs.

Note.—After weighing the substances he obtains, the candidate is to place the number of his examination paper on them, and hand them to the Superintendents of the examination, to be returned to the Department for examination.

SUBJECT XX. NAVIGATION.

EXAMINER, JOSEPH WOOLLEY, ESQ., LL.D.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

In all cases the number of the question must be placed before the answer on the worked paper.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions; viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Define *equator*, *meridians*, and *poles of the earth*. Draw two figures of the earth as it would be viewed—(1) from above one of the poles, and (2) from a point above any place on the equator. (The figures should be exaggerated to show any difference.) On each figure indicate the equator, a meridian, and a pole. (12½.)

2. Define *nautical distance*. Explain clearly what the Rhumb Curve is, and why it is of importance in Navigation. (12½.)

3. Draw a compass card, dividing one quadrant into angles of four points; the second quadrant into angles of two points; the third into angles of 22° 30′; and the fourth into angles of 11° 15′. Name only these last divisions. Define variation and deviation of the compass. (12½.)

4. Prove the formula—Dep. = diff. long. × cos. lat. What do you understand by *middle latitude sailing?* (12½.)

5. Describe the construction of the ordinary instrument for finding the rate of a ship in sailing. What is the use of heaving the lead? How is the nature of the sea-bottom ascertained? (12½.)

6. What do you mean by resolving a traverse? Show how you can do this without the aid of the Traverse Table. What is the use of the Traverse Table? Explain why it is necessary only to compute the table up to four points. (12½.)

SECTION II.

7. A ship sails S.E by S. from a place in latitude 43° 30′ N. for 85 miles. Find the latitude in. (8.)

8. A ship in latitude 51° 29′ N. and longitude 30° 20′ W. sails due east for 10 hours at the rate of 6 miles an hour. Find her longitude in. (8.)

9. Find by middle latitude sailing the true course and distance from A to B, given—

	Latitude.	Longitude.
A	32° 10′ S. ...	120° 20′ W.
B	40° 30′ S. ...	125° 40′ W.

(10.)

10. A ship sails from a place in latitude 12° 40′ S., longitude 29° 30′ W., 243 miles on a compass course, W.S.W. ½ W. (variation, ½ pt. W.; deviation, ¾ pt. W.). Find, by middle-latitude method, the latitude and longitude in. (13.)

11. Find the compass course and distance from Antogil Bay (Madagascar) to St. Denis (Bourbon); variation 15° W., deviation 2° 30′ W—

	Latitude.	Longitude.
Antogil Bay ...	16° 0′ S. ...	49° 50′ E.
St. Denis ...	21° 10′ S. ...	55° 30′ E.

(13.)

12. A ship in latitude 30° 10′ N., longitude 150° 20′ E. afterwards sails as follows—

True Courses.	Distances.
E.	8′
S.S.W.	36′
S.E. ½ E.	58′
N.E. by E.	25′

Find her latitude and longitude in. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* all or any of the questions.

21. Explain clearly between *true difference of latitude* and *meridional difference of latitude*. What do you understand by *Mercator sailing?* State what is the advantage of the chart used. How do you read off the distance between two places on the chart? (25.).

22. Describe fully the process of "swinging the ship." Explain the terms *induced*, *sub-permanent*, *permanent*, as applied to the magnetism of ships. (20.)

23. What precautions must be used in heaving the log? Explain clearly how the log-line and log-glass must be adapted to each other. Describe Massey's Patent Log and its use. (20.)

24. State the advantages and objections to great circle sailing. Show how to find the course on which a ship must start from A to sail along the shortest distance to B. Explain how to find a succession of points on the great circle between the two places. (25.)

25. Find the compass course and distance by Mercator sailing between Valparaiso (latitude 33° 2′ S., longitude 71° 35′

W.) and Juan Fernandez (latitude 33° 20′ S., longitude 79° W.; variation allowed, 13° 30′ E.; deviation 2° 30′ W. (15.)

26. Two places, A and B, are in the same latitude, S; their longitudes are A 5° 30′ W. and B 15° 30′ E.; their distance from each other is 700 miles. Find in what latitude they are situated. Also find their compass bearings from each other, variation at A being 1¼ point W., and at B 2¼ point W., deviation of A's compass being 8° 30′ E., and of B's, 10° 15′ W. (25.)

27. Find the shortest distance between two places, A and B, having given latitude A 46° 40′ N., longitude A 53° 3′ W., latitude B 51° 25′ N., longitude B 9° 29′ W.

Also find the initial course on the great circle from A to B. (30.)

28. January 30th, 1886, at noon, Easter Island (latitude 27° S., longitude 109° 10′ W.), bore by compass N.E. distant 9 miles, ship's head S. ½ E. (deviation 2° 30′ E.); afterwards sailed as by the following account. Find the latitude and longitude in on January 31st at noon. Variation 8° 30′ E. (40.)

H.	K.	$\frac{1}{10}$ths.	Courses.	Wind.	Leeway Points.	Remarks.
1	5	5	S. ½ E.	W. by S.	¼	Deviation 2° 30′ E.
2	5	8				
3	6	0				
4	6	5				
5	7	2				
6	6	0	S. by E. ½ E.	S.W.	1¼	Deviation 0° 10′ W.
7	5	5				
8	5	5				
9	5	0				
10	5	0				
11	4	0				
12	4	8	W.N.W.	S.W.	½	Deviation 8° 10′ E.
1	4	8				
2	4	5				
3	4	5				
4	4	2				
5	5	2				
6	5	8	S.W. by W ¼ W.	S.	¼	Deviation 2° 20′ W.
7	6	8				
8	6	2				
9	6	2				
10	7	5				
11	7	5	S.E. ½ E.	W.S.W.	0	Deviation 9° 20′ E.
12	7	0				

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* all or any of the questions.

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41. What is the use of the Table of Meridional Parts? Explain how the meridional parts for any point on the earth's surface may be calculated. Given the meridional parts for 75° 5′ (=6989·71). Find by an approximate method the meridional parts for 75° 10′. (50.)

42. A ship sails E. by S. by compass from A to B, 9 miles. At A the compass bearing of a rock, R, is E.N.E. and of a headland, H, E. by N. At B the compass bearing of R is N. by W., and of H, N.N.E. Find the magnetic bearing of the rock from the headland. Variation $1\frac{1}{2}$ point W.; deviation $\frac{1}{2}$ point E. (50.)

43. Explain clearly what you mean by *co-efficients* in formulæ embodying physical properties as exemplified in compass deviation formulæ. Describe how they are determined. Show what is the effect on the deviation of the compass when an iron ship is not sailing on an even beam. (50.)

44. Describe generally the hurricanes of the West Indies. Explain clearly why the wind veers as a circular storm passes over a ship hove to. When a ship is hove to within the area of a circular storm give a short rule for finding in what parts of the storm she is, from observing how the wind is veering. (40.)

45. A ship starts from A on the course N. 64° 12′ E. and sails on a great circle to B; she increases her distance from the equator till she gets into longitude 19° 26′ 30″ W. on the parallel of 51° 50′ 30″ N., and then diminishes it. Find the latitude and longitude of A and B, their difference of longitude being 43° 34′. (40.)

46. In fixing positions in surveying, what is the *Three-point Problem?* What conditions ought to be looked for in selecting the objects?

    What is the *danger angle?* Explain with a figure how it is used so that the danger indicated may be avoided. (40.)

47. Describe the theodolite, indicating clearly its principal parts and describing the several motions of the instrument. (50.)

48. Construct a Mercator's chart, on the scale of 1·8 inch to a degree of longitude extending from latitude 71° 30′ N. to 73° N., and longitude 55° W. to 58 W., taking out the meridional parts and drawing the parallels for every 30′.
Lay down a rock, A, in latitude 72° 10′ N., longitude 56° 5′ W., and the track and final position, B, of a ship which sails from this point 34′ N. by compass. Variation 75° W.; deviation 10° 20′ E. Take off the latitude and longitude in and state the magnetic bearing of A from B. (80.)

SUBJECT XXI. NAUTICAL ASTRONOMY.

EXAMINER, JOSEPH WOOLLEY, ESQ., LL.D.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

You are only permitted to *attempt eight* questions, viz., *four* out of each of the sections into which the paper is divided.

Section 1.

1. Define *polar distance, prime vertical, equinoctial points, altitude and azimuth of a heavenly body*. Draw diagrams explaining these definitions. (12½.)

2. What do you mean by *Greenwich date*? Explain clearly how to find the Greenwich date, having given the apparent solar time at a place of known longitude. Why is this problem important? (12½.)

3. Draw a sketch of a sextant sufficient to show clearly the course of two rays, one from the horizon, the other from a star, meeting in the observer's eye. Supposing the altitude of the star 40°, what would be the actual angle between the planes of the two mirrors? What would be the reading of the graduation on the arc supposing there is no index-error? (12½.)

4. In what part of the heavens is the correction for refraction greatest, and why? Draw a figure and explain by it what is meant by the dip. Show why there is no correction for dip in an observation by the artificial horizon. (12½.)

5. Define *amplitude of a heavenly body*. Prove the rule for finding the variation of the compass by amplitude of the sun. (12½.)

6. Investigate the method of finding the longitude by the chronometer, the sun being the observed body. (12½.)

Section II.

7. July 7th, 1886, at a place in longitude 25° 30′ W., the observed meridian altitude of the sun's L.L. was 50° 30′ 20″ (zenith N. of the sun.) Index corr. + 3′ 0″; height of the eye 27 feet. Required the latitude. (8.)

8. March 21st, 1886, at a place in longitude 84° E., the observed meridian altitude of the sun's Upper limb was 66° 32′ (zenith S. of the sun.) Index corr. 0; dip 4′ 24″. Required the latitude. (8.)

9. Find the true bearing of the sun from the following:—On July 8th, 1886, at 5 A.M., nearly in latitude 50° 42′ N., and longitude 95° W., the apparent altitude of sun's centre was 18° 20′ 30″. (10.)

10. July 11th, 1886, at 8^h 42^m P.M., mean time nearly, in latitude 58° 35′ N., and longitude 1° E., the sun set by compass N., 24° 10′ W., deviation 3° 20′ E. Find the variation. (10.)

11. September 20th, 1886, at 4^h 15^m P.M., mean time nearly, in latitude 56° 50′ N., and longitude by account 103° 15′ W.,

when a chronometer showed 11^h 30^m 50^s, the observed altitude of the sun's L.L. was 11° 5′ 30″; index corr. −2′ 40″; height of the eye above sea 30 feet.

On September 10th the chronometer was fast on G.M.T., 0^m 29^s, and its daily rate was 5·5^s losing.

Required the longitude. (14.)

12. March 12th, 1886, at 10^h A.M., mean time nearly in latitude 50° 50′ N., and longitude 2° 30′ W., when a chronometer showed 10^h 18^m 12^s, the observed altitude of the sun's L.L. was 56° 30′ 20″ (in artificial horizon); index corr. + 2′ 0″. Required the error of the chronometer on G.M.T. (16.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt all* or any of the questions.

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21. Explain the terms *horizontal parallax* and *parallax in altitude*. Assuming the formula parallax in alt. = hor. par. × cos. appt. alt. (Corrected for refraction.)

    Calculate the true altitude of the moon's centre, having given apparent altitude of moon's centre = 40° 20′ 30″ and horizontal parallax 55° 39″. (20.)

22. Investigate the rule for finding at what time a given heavenly body will pass a given meridian. Of what practical use is this problem at sea?

    At a place due south of Greenwich two bright stars are near the meridian on July 9th, about 9^h 12^m P.M. mean time, one in the southern and the other in the northern hemisphere; which are the stars? (20.)

23. Define *angular distance of two stars*. State clearly what you understand by the *celestial concave*. Explain *rational horizon* and *sensible horizon*, *dip of the horizon*. (15.)

24. Investigate a method of finding the latitude by "reduction to the meridian." (20.)

25. October 15th, 1886, in latitude by account 53° 20′ N., and longitude 50° E., a double altitude of the sun was observed at an interval according to the chronometer of 1^h 34^m 42^s.

Mean time nearly	Obs. alt. Sun's L.L.	Bearings.
9^h 45^m A.M.	25° 45′ 5″	S.S.E.
11^h 20^m A.M.	27° 31′ 50″	S.b.E.

The run of the ship in the interval was S. by W., 14 miles; index corr. + 2′ 30″, height of the eye 20 feet. Find the latitude at the second observation. (40.)

26. In finding the longitude, either by the chronometer or lunar distance, show by diagrams in what respect the work for determining the ship's mean time differs when the sun and when a star is used.

For August 9th, 1886, at 7 P.M., mean time nearly in latitude 50° 20′ N. and longitude by account 10° W.; take out the latitude and R.A. moon; and the time of the moon's crossing the meridian. Why would not an observed altitude of the moon at this time be favourable for finding ship's mean time? (25.)

27. On April 10th, 1886, in longitude 35° 20′ W. at $8^h\ 20^m$ P.M. mean time, the altitude of *Polaris* (corrected for the instrument, refraction and dip of horizon) is 44° 8′ 20″. Required the latitude.

At this place what would be the altitude of Polaris at its upper and lower culminations?

Draw a figure on the plane of the Equator, putting in the meridian, pole, zenith, mean sun, and First point of Aries. (30.)

28. July 7th, 1886, in the afternoon when chronometer showed $3^h\ 3^m\ 15^s$ (error $14^m\ 12^s$ fast) in latitude 54° 42′ W., longitude 0° 35′ W., the bearing of the sun was observed to be S. 86° 20′ W.; deviation 8° 0′ W. Find the variation. (30.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt all* or any of the questions.

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41. How is the *meridian distance* between two places measured? Distinguish between *primary* and *secondary* meridians. Describe two methods of determining meridian distances. What do you mean by *sea-rate.* Compute the meridian distance between Le Have and Prospect.

Sept. 4th	Chronometer	fast on	Le Have	mean time	$5^h\ 35^m\ 26{\cdot}7$
„ 5th	„	„	Prospect	„	$5^h\ 33^m\ 13{\cdot}47$
„ 10th	„	„	Prospect	„	$5^h\ 33^m\ 27{\cdot}25$
„ 11th	„	„	Le Have	„	$5^h\ 35^m\ 45{\cdot}33$

(50.)

42. Prove that
Error in hour angle : error in altitude : : sec. lat. : sin. azimuth. Find the error in the hour angle corresponding to an error of 1′ 30″ in the altitude at a place in latitude 20° 10′N. —(1) when the bearing of the body is S.S.E., and (2) when it is due E. (50.)

43. Draw a diagram showing the relative positions of the earth moon, and sun on the days referred to in pages 476–477 of the Nautical Almanac. Explain the following terms:—*superior tide, high tide, spring tide, height of tide.*

In making a survey of a harbour, mention the elements for a time table that must be observed. (50.)

44. At a place on the meridian of Greenwich in latitude 50° 30′ it is observed that the interval being the sun's centre being on the prime vertical and on the horizon is $3^h\ 30^m\ 48^s$. Find the sun's declination. If the latitude is north, what is the day of observation? and what if the latitude is south? Draw figures for the two days. (50.)

45. Investigate the method of clearing lunar distance by the common logarithmic tables. Find the true distance of the moon from the sun by the common logarithmic tables only, having given

	Sun.	Moon.
Apparent altitude	17° 39′ 30″	24° 13′ 45″
True zenith distance	72° 23′ 15″	74° 56′ 45″

Apparent distance of centres 111° 20′ 45″ (50.)

46. Define *mean solar time* and *sidereal time*, with diagrams. Explain clearly the meaning of *acceleration of sidereal on mean solar time* and *retardation of mean solar on sidereal time.*

If an interval of duration expressed in mean solar time be M, and expressed in sidereal time be S, show that $M + \cdot 002738\ M = S;\ S - \cdot 002731\ S = M$.

In what problems in Navigation are the tables calculated from these formulæ used? Where do you find the tables?

Given the sidereal time at any instant, explain with a figure how to find the mean time at the same instant. (50.)

47. Explain with the aid of a diagram the phases of the moon.

Define *lunation*, *age of moon*, and *epact*. Give the epact for 1886, and hence find that for 1883.

Define *moon-culminating stars*, and describe the use of the table given in the Nautical Almanac. (50.)

48. Given the elapsed time and change of declination in the interval, investigate an expression for the equation of equal altitudes. (50.)

SUBJECT XXII. STEAM.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

1. In improving the old atmospheric engine Watt laid down the rule that the cylinder in which the steam did its work should be kept as hot as the steam which entered it. What special provisions did he make for carrying out this rule? Explain your answer by referring to such sketches as may be required. (20.)
2. Name the three principal valves connected with the steam cylinder of a single-acting pumping engine. State which are opened and which closed—(1) when the piston is at the top of the cylinder and beginning to descend; (2) when the piston is at the bottom of the cylinder and beginning to ascend. (15.)
3. To what causes do you attribute the imperfect vacuum in the condenser of a steam engine? Describe the barometer gauge for a condenser, and explain its action. (15.)
4. Sketch in section a long D slide valve together with the steam ports and passages. Explain the action of the valve, and show the manner in which the exhaust steam is passed to the condenser. (15.)

5. The barrel of a single-acting air pump being vertical, sketch a section through it, showing the bucket or piston with metallic ring packings, and an indiarubber valve and guard, also show the gland and packing of the pump rod. Sketch also the foot and delivery valves, and show their position and connection with the barrel of the pump. (25.)

6. Explain the manner in which the reciprocating motion of the piston in a locomotive engine is converted into the rotatory motion of the crank shaft. What are the dead points? Show by the principle of work that there is no loss of power by the intervention of the crank, friction being disregarded. (15.)

7. Sketch a section through a Cornish double-beat or Crown valve, and explain the principle of its construction, stating its advantages over an ordinary disc valve. (15.)

8. Explain the advantage of working steam expansively and with condensation. Steam is admitted into a cylinder at 30 lbs. above the atmosphere, which is taken at 15 lbs. per square inch, and is cut off at a certain point and then expands to a pressure of 5 lbs. below the atmosphere. If the length of stroke be 4½ feet, at what point is the steam cut off? (20.)

9. Sketch a section through the fire box of a locomotive boiler, showing particularly the method of supporting the flat surfaces. (15.)

10. Sketch a sectional elevation of a vertical direct-acting engine. In such an engine where would you place the condenser and air pump? (20.)

11. Describe the construction of an eccentric for working the slide valve of an engine, and show that it gives the same motion as a crank and connecting rod. (15.)

12. Sketch the crank shaft end of the connecting rod of a marine engine, and describe the means employed for lubricating the rubbing surfaces. (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

21. In a jet condenser the temperature of the injection water is 60° F., that of the water after condensation is 100° F., and the latent heat of the steam which enters the condenser is 1,016 thermal units, the temperature of the steam being then 140° F.; find the number of pounds of injection water for each pound of steam condensed. (40.)

22. The diameter of the cylinder of an engine being 53 inches, the stroke 5 feet, and the number of revolutions 30 per minute, find the mean pressure of the steam to develop 600 indicated horse-power. (30.)

23. Explain the principle of the compound or double-cylinder engine. Sketch in section the cylinders, condenser, and air pump of a compound cylinder beam engine. (40.)

24. Explain, with a sketch, the principle of Watt's parallel motion. (30.)

25. Sketch and describe an escape valve as fitted to the cylinder of a marine engine. Why is such a valve required, and where is it placed? (30.)

26. Find the thickness of iron plates in a boiler shell 6 feet 4 inches in diameter, for a pressure of 40 lbs., the greatest tensile stress permissible in the material being 5,000 lbs. per square inch. (35.)

27. Given that the travel of a slide valve is 5 inches, outside or steam lap $\frac{3}{4}$ inch, and the angle of advance $22\frac{1}{2}$°, find graphically, or otherwise, the position of the crank at the point of cut off. (40.)

28. Describe and explain, with sketches, the mechanism of a reversing motion for a locomotive engine. (35.)

29. A motion of 1 inch in the pencil of an indicator, as due to steam pressure, represents a pressure of 20 lbs. on the square inch. What is the H.P. of an engine, making 90 revolutions per minute, the diameter of the piston being 10 inches, the length of stroke 20 inches, the area of the indicator diagram 8 square inches, and its length 5 inches? (40.)

30. Describe, with a sectional longitudinal sketch, Giffard's injector, and explain the manner in which it acts. What are the advantages of this apparatus as compared with an ordinary feed pump? (40.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to *attempt more than six* questions.

The value attached to each question is shown in brackets after the question.

41. Describe, with a sketch, Ramsbottom's method of supplying the tender of a locomotive with water while running. In what way can you estimate beforehand the speed of the train in order that water may be lifted into the tender? (50.)

42. An engine uses 10 lbs. of steam per minute, the feed temperature is 60° F., the boiler temperature 300° F., and that of the condenser 104° F. What is the theoretical maximum efficiency of the engine? State Regnault's formula for the total heat of steam at a given temperature, and deduce the amount of heat which each pound of steam has received in the boiler. What horse-power would be developed if the engine worked as a perfect engine? (60.)

43. In a refrigerating engine, atmospheric air is compressed and subsequently cooled; it is then allowed to expand and do work whereby its temperature is greatly reduced. Give the theory of the process, and find how much the temperature of a given mass of air is raised by a given amount of compression in a vessel impervious to heat. (75.)

44. Explain and prove the truth of Peaucellier's method of obtaining a straight line motion. Arrange the dimensions of an instrument for giving a straight line path of 12 inches. (50.)

45. Describe a valve motion for reversing an engine where a single eccentric is keyed to the shaft. This question refers to Hackworth's valve gear, or others of the same character. (70.)

46. Describe, with sketches, the construction and arrangement of the cylinder, steam ports, and passages, together with the slide valve of a marine oscillating engine, and show the manner in which the valve gear is adapted to the oscillating cylinder. (65).

47. Sketch in longitudinal section the boiler and fire-box of a locomotive engine. Draw separately a regulator valve and a safety valve, explaining the action of each, and pointing out any advantages of construction in the form you select. (65.)

48. Sketch a double-ported slide valve, with the relief ring at the back of the valve. Show also in section the ports in the cylinder with the valve in the position it would have when the piston is at the end of a stroke. Describe the operation of setting the slide valve of a marine engine. (65).

SUBJECT XXIII. PHYSIOGRAPHY.

EXAMINERS, PROFESSOR JOHN W. JUDD, F.R.S.,
AND J. NORMAN LOCKYER, ESQ., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

The *first three* questions must be *attempted* by you, and you are then at liberty to select five others from among the remaining questions on the paper.

The value attached to each question is indicated by the numbers in brackets.

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1. Name the *two* chemical elements which are found in the greatest abundance in the earth's crust. State the nature of these elements, and the condition in which they occur. Name *five* other elements which also occur very abundantly in minerals and rocks. (15.)
2. State the chief differences in the properties of water in its solid, liquid, and gaseous states. Under what conditions are these several states assumed by water? (15.)
3. How has it been proved that some parts of the land of the globe has undergone elevation in recent times? (15.)

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4. What are the chief substances present in the atmosphere in addition to oxygen and nitrogen, and in what proportions do these additional substances occur? (11.)

5. How do the waters of springs, rivers, and the sea differ from pure water? (11.)

6. In what way is carbonate of lime separated from a state of solution in waters, to form the substance of limestone rocks? (11.)

7. Explain the action of frost in breaking up rock-masses. Where does this kind of action go on most rapidly? (11.)

8. What is a volcanic dyke; what is it like; and how is it formed? (11.)

9. What is a maximum and minimum thermometer, and for what purposes is it used? Describe any form of the instrument with which you are acquainted. (11.)

10. State what you know concerning the form and composition of a crystal of quartz. (11.)

11. Why, in this country, does the sun appear so much higher in the sky at noon in summer than it does in winter? (11.)

12. Of what chemical elements are plants chiefly composed, and how does coal differ in composition from the plants from which it was formed? (11.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *five* of the following questions, and *the two which stand first upon the paper* must be included among these.

The value attached to each question is indicated by the numbers in brackets.

---

21. Describe the instruments by which the distribution and intensity of terrestrial magnetism have been determined. (23.)

22. What is meant by "the pressure of the atmosphere," and how is the amount of that pressure determined and expressed? Within what limits is the pressure of the atmosphere liable to variation, and what are the causes of this variation in pressure? (23.)

---

23. Why do cyclones and anticyclones move in opposite directions on the north and south of the equator respectively? (18.)

24. In what position, with respect to the centre of impulse of an earthquake, are its destructive effects most severely felt? (18.)

25. Describe the physical characters and the chemical composition of the minerals called felspars. (18.)

26 How has the distance of the moon been determined? (18.)

27. What is the cause, and what the result, of the precession of the equinoxes? (18.)

28. State Kepler's Laws. (18.)

Honours Examination.

INSTRUCTIONS.

You are permitted to *attempt* all, or any, of the questions.

The value attached to each question is the same.

41. What are the chief sources of error in observations directed to the determination of the rate of increase in temperature within the earth's crust?

42. Describe the composition and characters of the chief types of vitreous rocks.

43. State what you know concerning the distribution of spots and prominences on the sun's surface.

44. Compare the atmosphere of the major planets.

45. Give an account of the results which have been obtained by recent researches in connection with one or other of the following subjects:—
    (*a*) The velocity of light.
    (*b*) The nature of the great earth-movements which take place during the formation of mountain-chains.

SUBJECT XXIV. PRINCIPLES OF AGRICULTURE.

EXAMINERS, PROFESSOR HENRY TANNER, M.R.A.C., F.C.S., and PROFESSOR JOHN WRIGHTSON, M.R.A.C., F.C.S.

GENERAL INSTRUCTIONS.

If the Rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions. You must *attempt three* of the first *four* questions on the paper; the remaining five you may select from any part of the paper.

Each question admits of an answer carrying an equal number of marks.

1. Describe the way in which our different kinds of soil are formed.
2. What chemical materials are found in soils, and into what two groups may they be divided?
3. What food do plants make use of for promoting their growth, and how do they get the food they require?
4. What do we mean by a good rotation of crops, and state some of the advantages we gain by it

5. Why does farmyard manure differ so much in its fertilising value?
6. Take any one of our artificial manures, and give an account of its origin or mode of production, and state the advantages gained by its use on the land.
7. Why do we plough and otherwise cultivate soil before sowing the seed?
8. What special advantages are gained by Autumn cultivation?
9. How does the drainage of land render it better able to yield good crops?
10. What are the differences between light and heavy soils, and what crops are best suited to each?
11. What substances are found in our farm crops which are valuable as food? What duties do they respectively perform in the animal body?
12. How may we economise the use of food for farm stock?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *six* questions.

You must *attempt two* of the first *three* questions on the paper. The remaining four you may select from any part of the paper.

Each question admits of an answer carrying an equal number of marks.

---

21. Show how the subsoil influences the productive powers of the soil, giving illustrations from your reading or experience.
22. Upon what classes of arable land is the winter folding of sheep to be recommended, and in what circumstances would such a system be injurious?
23. What is the general composition of a fair "superphosphate"? From what natural sources and by what process are these useful manures made?

---

24. Point out the chief effects of a dressing of superphosphate upon a turnip crop, and show that it tends to secure a safe and regular crop.
25. Describe the attack of the "turnip fly," and prescribe measures for preventing or counteracting this insect pest.
26. What general principles of tillage and management may be recommended for destroying insect life and preventing insect attacks on farms?

27. Describe the preparation of a piece of clover-lea for wheat, including the sowing of the crop.

28. Construct a workable rotation of crops for heavy land suitable for the present range of prices.

29. What are the leading differences in the water economy of stiff soils and free soils, both of which are suffering from wetness? Clearly point out these differences, and show how they affect the methods employed in order to drain these soils.

30. Describe the systems of preserving fodder crops known as *Ensilage*.

31. What rules would you observe in order to produce a first-rate quality of hay?

32. Enumerate the advantages of covered yards for live stock.

33. How would you proceed in order to produce artificial swarming of bees? Describe the entire process.

34. Describe the Brittany system of making butter.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to *attempt* more than *six* questions in this paper.

Each question admits of an answer carrying an equal number of marks.

41. How would the course of husbandry most desirable for a farm be influenced by the character of its soil and climate?

42. What are the relative advantages of enriching the land by the direct application of artificial manures, and by the production of additional manure arising from the use of purchased food for stock?

43. Point out errors of practice occasionally observed in the irrigation of land, and state your reasons for objecting to this course of procedure.

44. Describe the various plans now employed for the production of ensilage, explaining their respective merits and the principles upon which such practices are based.

45. State the conditions of growth most favourable for the production of "roots" and corn, each possessing its highest nutritive character.

46. What changes take place in the malting of barley? What are the relative feeding properties of malt and barley?

47. Describe the advantages of cross-fertilization in plants, and show how these are secured.

48. Describe any one process of cheese-making, and explain the action of the agencies employed.

49. What are the chief points of character which distinguish fowls of the highest quality for table use? How may these points of character be established?

50. Give an example of the assistance science has rendered to some one section of farm practice. State the principles upon which such improved practice is based.

SUBJECT XXV. HYGIENE.

EXAMINER, PROFESSOR W. H. CORFIELD, M.A., M.D. (OXON).

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours Paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

The same value is attached to each question.

1. What natural forces may be utilised in the ventilation of rooms? Give sketches of some simple appliances which may be used for this purpose.

2. What refuse matters are produced in a kitchen? What should be done with them?

3. What are proper sources of drinking-water for villages and for towns? How may a suspected water be rendered harmless for drinking?

4. Why is sleep necessary? Do children or adults require more sleep, and why?

5. What is the relative importance of the changes produced in air by respiration?

6. Compare the flesh of fish with butcher's meat as food. Mention some important differences in the flesh of various kinds of fish.

7. Why do children require to be well clothed? What are the best materials for their clothes, and how should they be cleaned?

8. Why is the drainage of the soil of a town necessary, and how should it be carried out? In what kinds of soil is drainage most essential?

9. State the compositions of (*a*) an "average" diet, (*b*) a "subsistence" diet; and give an example of the former with ordinary foods.

10. What food substances especially aid the action of the intestines? What is the importance of regular action?

11. What are the physiological effects of alcohol and of alcoholic drinks used in moderation and in excess?

12. A person has been run over by a cab, his arm is apparently broken and is bleeding fast; what would you do?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions

The same value is attached to each question.

21. Compare and contrast the various cereal grains as to their composition and economic uses.

22. Contrast the physiological effects of breathing rare and dense air, and of living at different altitudes.

23. Under what circumstances would carbonic oxide be found in the air of a room? What effects does it produce?

24. What are the materials used for filtering water on the small scale? How do they act? What points should be attended to in the construction of a domestic filter?

25. Sketch and describe a good form of hopper water-closet. How should it be supplied with water?

26. Describe some stoves with arrangements for the admission of warmed fresh air into rooms; give a sketch of one of them.

27. Describe the rain-gauge, and the method of graduating its measuring glass. If one inch of rain falls in 24 hours, how many gallons of water can be collected during that time from a roof 60 feet by 40 feet?

28. What are the chief substances used for disinfecting air? How do they act?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

The same value is attached to each question.

41. What are the provisions of the Public Health Act for the prevention of infectious diseases?

42. If six persons are in a room containing 3,000 cubic feet, and have a supply of 2,000 cubic feet of air per head per hour, how much carbonic acid will be contained in the air of the room at the end of four hours? Could this amount of air be supplied without draught? Would it be sufficient?

43. What diseases have been shown to be spread by the agency of milk? In what ways does the milk become contaminated? What precautions should be taken to prevent such contamination?

44. Describe the business of a bone-boiler, or of a gut-scraper, and frame a code of bye-laws to regulate it.

45. Describe in detail, with sketches, the construction of a good valve water-closet. What are the arguments for and against the use of this form of closet?

46. What is the law of increase of a population? How is its probable future increase calculated? If the census population of a town was 31,563 in 1871, and 39,482 in 1881, show how you would proceed to calculate the population for midsummer 1886.

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LONDON, S.W.

EXAMINATION PAPERS

FOR

SCIENCE SCHOOLS AND CLASSES.

May, 1887.

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EXAMINATION PAPERS
FOR
SCIENCE SCHOOLS AND CLASSES.
MAY, 1887.

SUBJECT I. PRACTICAL PLANE AND SOLID GEOMETRY.

EXAMINER, CAPTAIN G. S. CLARKE, R.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The constructions may be left in pencil, provided they are distinct and neat, and that the construction lines are shown. They must be strictly geometrical and not the result of calculation or trial. In the absence of those lines which are essential to a correct solution no marks will be awarded, however correct the result may appear.

Lines parallel or perpendicular to others may be drawn mechanically without showing any construction. Lines may be bisected by trial.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Questions marked (*) have accompanying diagrams.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Only *eight* questions are to be attempted.

A.

Plane Geometry.

*1. Draw the given figure *full size,* adhering strictly to the figured dimensions. (8.)

*2. Reduce the given figure to a square of equal area. (8.)

3. Construct a triangle whose sides *ab*, *bc*, *ca* are 3¼", 2⅜", and 2" respectively. On *ac* construct a second triangle, *adc*, whose vertical angle *adc* is equal to the angle *abc* and the side *ad* 1⅝". N.B. The angles upon the same base and in the same segment of a circle are equal. (8.)

Solid Geometry.

4. *a.* Show by their traces two vertical planes making 60° with each other, and with the vertical plane of projection.
   b. Show by their projections any two equal parallel lines not parallel to either plane of projection. (10.)

*5. State precisely what is represented by each of the four given figures (A), (B), (C), (D). (10.)

6. A is a point in the vertical plane 1¼" above the horizontal plane; B is a point in the horizontal plane 1¾" from the vertical plane. The real distance from A to B is 3". Draw the plan and elevation of the line joining A and B. (12.)

*7. *a'* is the elevation of a point in the given plane *lom*; *b* the plan of a point in the given plane no_1p. Determine the real length of the line joining these points. (12.)

*8. A vertical plane, of which *ht* is the horizontal trace, cuts the two given planes. Draw the elevations of the intersections, and determine the real angle they contain. (14.)

*9. *ab*, a line in the horizontal plane, is the base of a triangle, the real lengths of the other sides of which are 2¼" and 1¾". The height of the vertex is 1½" above the horizontal plane. Complete the plan and draw the elevation of the triangle. (14.)

10. Draw the plans of two spheres, 1" and 2½" in diameter, touching each other, and both planes of projection. (14.)

11. Draw the plan of a cube of 2¾" side with one axis vertical. (14.)

*12. Four equal bricks are arranged as shown, their side faces being all in one plane. The dimensions of each brick are 9" × 4½" × 3". Draw the plan of the pile, and an elevation on a plane inclined at 35° to the long edges of the three lower bricks. *Scale ⅛ full size.* N.B. The figure is *not* to be merely reproduced. (14.)

*13. Make a sectional elevation of the pile (Q. 12) by a vertical plane containing the diagonals of the horizontal faces of brick A. (14.)

Graphic Arithmetic.

*14. Determine by construction a line representing the sum of the given lines A, B, divided by C. *Unit* $1\frac{1}{8}''$. (10.)

15. Supposing that the area of a circle is $\frac{22}{7}r^2$, where r is the radius; obtain by construction and write down the length of a line representing the area of a circle 3″ in diameter. *Unit* 1″. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

Only *eight* questions are to be attempted.

B.

Plane Geometry.

*21. Two lines, including a given angle, touch two given circles as shown. Trace the locus of the intersection of the lines. (16.)

*22. Through the given point p draw two lines cutting the two given lines in such a way that the included area is $3\frac{1}{4}$ square inches. (18.)

*23. Four equal rods, ab, bc, cd, da form a frame jointed at the angles. The frame is also pivoted at a. The point c moves on the circumference of the given circle. Draw the curve traced by the point x on the bar bc. (20.)

Solid Geometry.

*24. Two planes are given by their traces aob, cod. Draw the projections of a sphere 2″ in diameter touching the given planes, and having its centre in the horizontal plane. (25.)

*25. mon is a given plane. Determine the vertical trace of a second plane having the given line ht as its horizontal trace, and such that the real angle contained between the traces is the same as that contained between the traces of the given plane. (22.)

*26. a, b, c are points on the horizontal plane. Determine the position of a point v on the given line db, such that the triangles vab vcb, if folded out flat about the line db, shall form a single triangle. *Unit* 0·1″. (22.)

*27. The end elevation and a portion of the plan of two adjacent ridge roofs is given. Determine on plan the shortest distance measured on the roof surface from *a* to *b*. (22.)

*28. The three given parallel lines are the plans of portions of the edges of a triangular prism. Determine the plan of a sphere inscribed in the prism, and having 16 as the index of its centre. *Unit* 0·1." (26.)

*29. An oblique triangular pyramid, *vabc*, having its base, *abc*, on the horizontal plane, penetrates a vertical right cylinder, of which the arc *de* struck from *v* as centre, is a portion of the plan. Draw an elevation, on a line parallel to *ac*, of the hole made in the cylinder, supposing the pyramid removed. *Unit* 0·1". (30.)

*30. The plan of an inverted right cone with its vertex on the horizontal plane is given. The height of the plane of the base is 25. Determine the scale of slope of a plane containing the given point *p* and tangent to the cone. *Unit* 0·1". (22.)

*31. The given figure represents the elevation of a square-headed bolt with a conical shank standing on the horizontal plane. The projections *r*, *r'* of one of the parallel rays of light are given. Draw the bolt *full size*, and obtain the shadow cast on the horizontal plane. (26.)

*32. Make an isometric view of the bolt (Q. 31), drawing it full size. An isometric scale is not to be used. (25.)

*33. A right cylinder lies on a truncated right cone as shown, the axis of the cylinder passing through that of the cone. Draw the figure *full size* and make a sectional elevation of the two solids by a vertical plane passing $\frac{1}{2}$" from the axis of the cone, and making 50° with the axis of the cylinder. (34.)

Graphic Statics, &c.

*34. Obtain by construction lines representing the areas A, B, C, into which the given figure is divided. *Unit* $1\frac{1}{4}$". (16.)

*35. Five given forces act as shown at the point O. Determine by construction two forces acting along the given dotted lines which will keep the point O in equilibrium. Write down the magnitudes and indicate the directions of these forces. Use a scale of 1" = 100 lb. (22.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary Paper. Only *eight* questions are to be attempted.

C.

Plane Geometry.

*41. *abcd* is a field; *ce* a hedge. How must the hedge be carried on in a straight line so as to divide the field into two equal parts? (40.)

*42. Draw a rectangular hyperbola, having given the focus F and an asymptote AA. (35.)

*43. Obtain the form of a cam plate to be keyed on to a shaft, A, and impart motion to a roller B, the centre of which travels on the given dotted line. In one-third of a revolution of the cam shaft, B is to be raised at a uniform speed to the position C. It is then to remain at rest during one-sixth of a revolution, to rise to D at a uniform speed in one-quarter of a revolution, and to fall back from D to B in one-quarter of a revolution. (45.)

Solid Geometry.

*44. The traces of two planes are given, and *ab* the plan of a line lying in one of them, *mon*. AB is one side of an equilateral triangle, of which the vertex C is in the other given plane. Complete the plan, and draw the elevation of the triangle. (40.)

*45. Determine the projections of a line $2\frac{1}{2}''$ long with one extremity in each of the given planes and inclined at the same angle to both. The centre of the line to be $\frac{3}{4}''$ above the horizontal plane. (40.)

*46. Trace the locus of the centre of a circle 2″ in diameter, touching the two given lines *ab*, *a′b′*; *cd*, *c′d′* supposed indefinitely produced. (45.)

*47. A rod, *ab*, is balanced at the point *o*, about which it also vibrates through the angle shown. While making two-thirds of a complete revolution, *ab* swings from the position *a′b′* to *a″b″*. Draw the plan of the locus of one of the extremities of the rod during one whole revolution. (40.)

*48. Draw a line through the given point *c* to pass $1\frac{1}{2}''$ from each of the two given points *a*, *b*. State the conditions of possibility of this question. *Unit* 0·1″. (50.)

*49. The given figure represents the plans of two equal anch rings interlocking. Make a vertical section on the li *xy*, distinguishing the sectional parts of the two rings (50.)

50. A surface is generated by a line passing through a fi vertical axis and making a constant angle of 35° with while revolving round it at a uniform speed. Durin complete revolution, the point of intersection of generating line and the axis moves 2½″ along the latt Draw the section of the surface so generated by a pl parallel to and 1″ from the axis. (50.)

*51. Determine the shadow cast by the given bracket on t wall to which it is fixed. The rays of light are parall and two elevations, *r′*, *r″*, of a ray are given. (50.)

*52. Make an isometric view of the given bracket. N.B. A isometric scale is not to be used. Dimensions may taken direct from the figure. (45.)

*53. The sketch plan shows the position of the given brack with respect to the plane of the picture. The statio point is 6″ from the picture plane and ¾″ below the lev of the top of the bracket. Draw a perspective view the bracket. N.B. The sketch plan is to be taken on as giving the position of the bracket. (60.)

Graphic Statics.

*54. Determine by construction the centre of gravity of th given figure. (40.)

*55. Draw a stress diagram for the given simple truss under a single load w = 1800 lb. applied as shown. Distinguish between bars in tension and in pressure. Scale ⅛″ = 100 lb. (50.)

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

EXAMINERS, PROF. T. A. HEARSON, M. INST. C.E., AND J. HARRISON, ESQ., M. INST. M.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

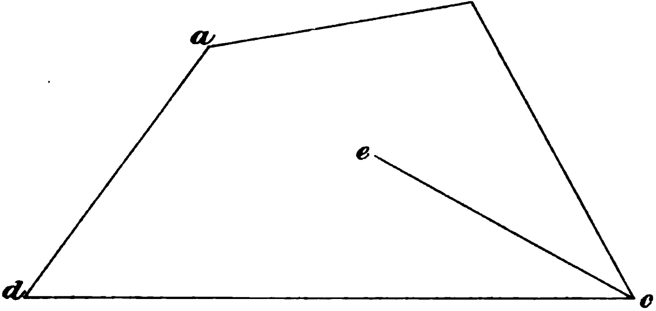
Put the number of the question before your answer.

SUB

The diagrams are to be pric

Failing th

Nº 41.



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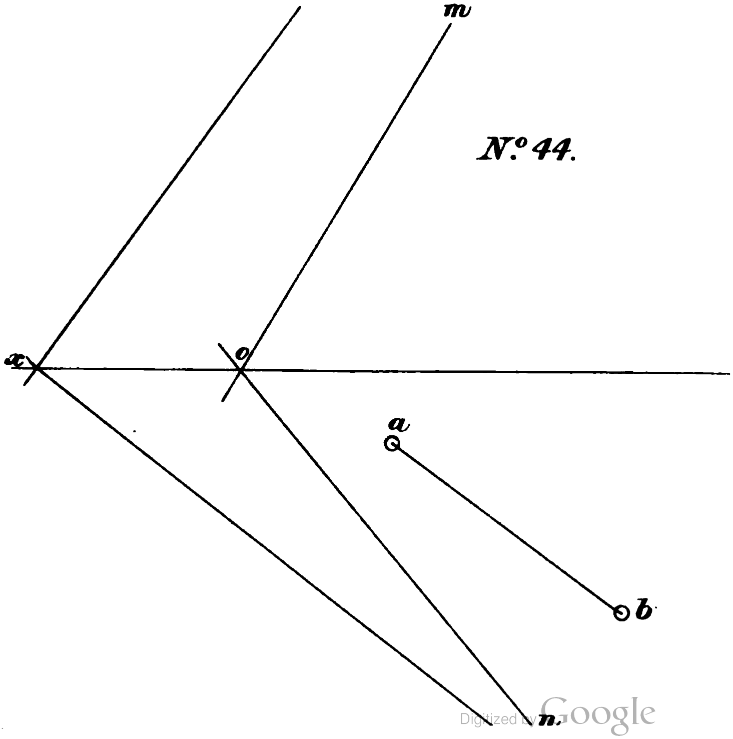

C.

(continued)

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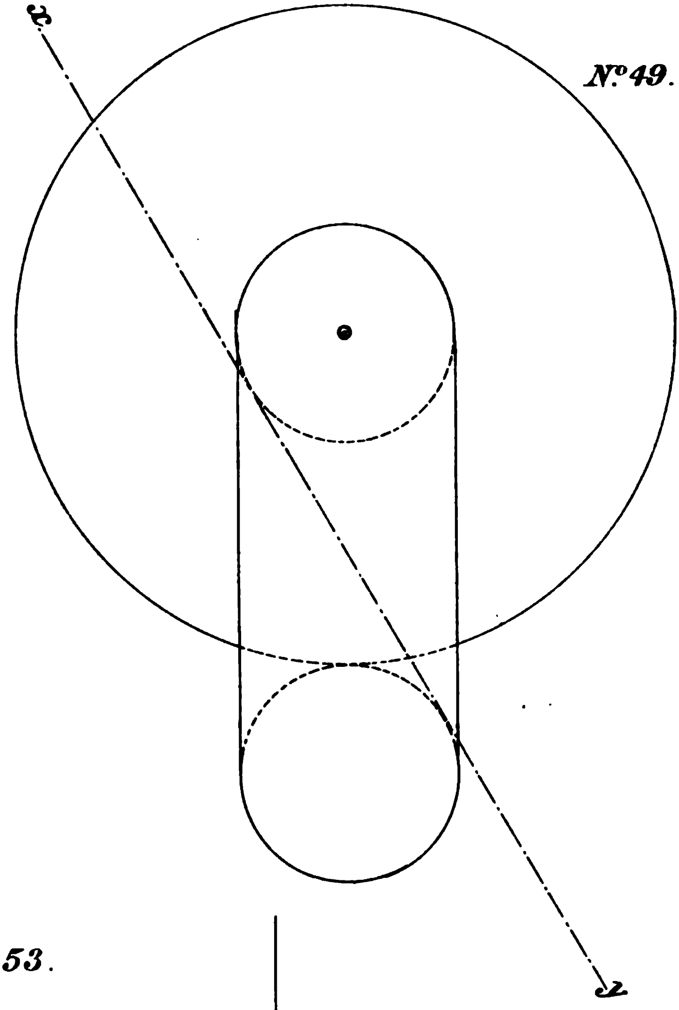
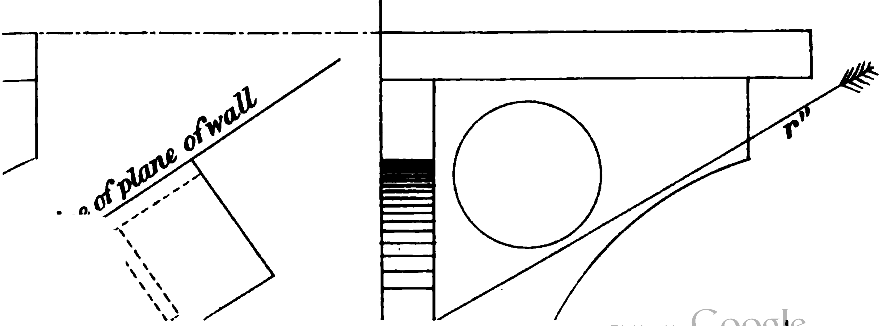
Nº 49.



51, 52, 53.



You are expected to prove your knowledge of machinery, as well as your power of drawing neatly to scale. You are therefore to supply details omitted in the sketches, to fill in parts incomplete, and to indicate, by diagonal lines, parts cut by planes of section.

No credit will be given unless some knowledge of projection is shown, so that at least two views of one of the examples will be required properly projected one from the other. The centre lines should be clearly drawn. The figured dimensions need not be inserted.

Your answers should be clearly and cleanly drawn in pencil. No extra marks will be allowed for inking in.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

A single accent (') signifies *feet*; a double accent (") inches.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Answer briefly any three, but not more than three, of the following questions, and draw two, but not more than two, of the examples.

Questions.

(*a.*) Explain how the piston rings in Example 1, Diagram D, are made, so that the piston may work steam-tight in the cylinder. How are these rings got into place? (8.)

(*b.*) Give two views of a double riveted lap joint for boiler plates. (8.)

(*c.*) Show by sketches how a wheel is fixed on a shaft by means of a sunk key. Explain how the key may be withdrawn when it cannot be driven from the point end. (8.)

(*d.*) Give sketches showing the construction of a conical metal lift or puppet valve and seating. (10.)

(*e.*) With the aid of sketches explain how a piston rod is made to work steam-tight through the end of the cylinder. (10.)

(*f.*) Explain how the slotting machine ram of Example 3, Diagram D, may be made to move up and down when at work. How is the length of the stroke altered, and what is the object of the slotway in the upper part of the ram? (10.)

Examples to be Drawn.

Diagram D.

1. Piston for steam-engine. Draw and complete the two views shown, the top half of the left-hand view to be in section. Scale ½ size. (30.)
2. Plan and sectional elevation of a footstep bearing for an upright shaft. Draw and complete these views. Scale ¼ size. (35.)
3. Ram of slotting machine. Draw and complete the two elevations shown. The tool-holders must be drawn in their proper positions in the ram, and not separate as in the diagram. Scale ¼ size. (35.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions above.

Answer briefly any three, but not more than three, of the following questions, and draw the example given.

Questions.

(*g.*) Give sketches and a description of some method of providing for the expansion and contraction of a long length of steam pipe. (15.)

(*h.*) State the characteristic properties of cast iron and wrought iron. Mention several examples of machine details in which the metal used is selected on account of the possession of certain of these properties. (15.)

(*k.*) Show the construction of a crank-shaft bearing, which is provided with means of adjustment for horizontal and vertical wear. (20.)

(*l.*) Give two views, with figured dimensions, of a knuckle or fork joint suitable for connecting two rods of 1½" diameter. Describe the process of machine-shaping the joint. (20)

(*m.*) Describe with sketches the construction of stocks and dies used for the cutting of screw threads. (20.)

(*n.*) What is the use of the vertical links shown inside the spring of the safety-valve in Diagram E? How can the tension of the spring in this valve be adjusted? Why is the end fulcrum of the lever provided with a hinged joint? (20.)

Example to be Drawn.

Diagram E.

Ramsbottom's Safety Valve. Draw and complete the two views shown, the left-hand view being one half in section and the other half in elevation, and the right-hand view being a section on AB.

Also give a plan, one side of which shall be a section through CD. Scale ½ size.

N.B.—To get these views properly on your paper, the foot of the flange in elevation should be placed 4½ inches (actual size) from the bottom of the sheet. (140.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions above.

You are permitted to answer only *eight* of the following questions.

The sketches required in answer to these questions may be in pencil, and need not be drawn to scale, but should be neat and in good proportion. The written answers must be in ink, and may be written on foolscap paper, which can be obtained on application to the superintendents of the examination. Each sketch should be made in immediate connection with the answer to which it refers.

41. Give an account of the extension produced in a mild steel bar by a gradually increasing tensile load. Draw a diagram the area of which will represent the dynamical strength of the bar, or the amount of work required to rupture it, and give an approximate numerical estimate of this area for a specimen 10″ long and 1 square inch in section. (20.)

42. Fig. 1 shows a centre line sketch of a loaded crane. The end B of the jib AB is forked to receive the chain pulley; there are two tie rods, BC, one on each side of

the jib, and the joint B is completed by a pin on which the pulley is mounted. Draw a diagram by which the stress on jib and tie rods may be ascertained, and determine the greatest shearing force on the pin. (25.)

Fig. 1.

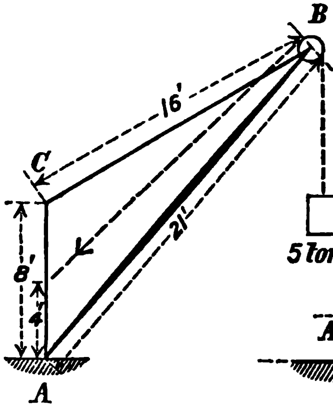
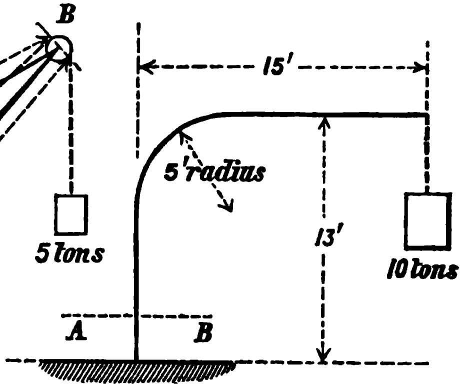


Fig. 2.



43. In Fig. 2 is shown the centre line of the jib of another type of crane. Estimate the bending moment at several sections, and draw a diagram representing the bending moment at all sections of the jib. Give a sketch of a suitable form of section at AB, and explain how the greatest stress at this section is to be calculated. (25.)

44. Determine the diameter of the eight bolts of a flange coupling for a shaft 14" diameter which is subjected to torsion only, the diameter of the bolt circle being 23". Sketch the coupling, giving figured dimensions. (25.)

45. Explain the importance of considering the stiffness as well as the strength of parts of a structure in determining their suitable transverse dimensions.

A beam of uniform section is supported at the ends and loaded in the centre. Calculate the ratio of depth to span in order that the deflection may not exceed $\frac{1}{1000}$th of the span when the maximum stress is 8,000 lbs. per square inch, the modulus of elasticity being 28,000,000. (25).

46. Investigate an expression for the moment of friction of a flat pivot, stating the assumption made as to the distribution of pressure.

Find the H.P. lost by the friction of a footstep bearing the diameter of which is 4", the total load on it being 3,000 lbs., the number of revolutions 100 per minute, and coefficient of friction ·06. (25.)

47. The fly-wheel of an engine of 4 H.P., running at 75 revolutions per minute, is equivalent to a heavy rim 45″ diameter, weighing 500 lbs. Estimate the ratio of the kinetic energy in the fly-wheel to the energy exerted in a revolution, and determine the greatest and least speed of rotation when the fluctuation of energy is one-fourth of the energy of a revolution. (25.)

48. Explain the effect of the change of velocity of the reciprocating parts of an engine in causing forces tending to displace the engine.

Estimate the greatest displacing force due to a set of reciprocating parts weighing 350 lbs., the engine making 400 revolutions per minute, the length of stroke being 2′, and connecting rod 4′ 3″. (25.)

49. Draw Zeuner's slide valve diagram for a steam-engine having given, maximum width of opening for steam $1\frac{5}{16}$″, lead $\frac{1}{4}$″, the release being at $\frac{9}{10}$ths stroke with no inside lap; and thereby determine the travel, angle of advance, outside lap, and point of cut-off. (25.)

50. Give sketches of a construction whereby a quick return motion is given to the ram of a slotting or shaping machine, in which the length of the stroke and the position of its centre may be adjusted. (20.)

51. Describe and give sketches with dimensions, showing the methods of securing the ends of a stay-tube to the tube-plates of a marine boiler. Give the calculation for the strength of a stay-tube. (20.)

52. Sketch and describe a method of fitting a liner in the cylinder of an engine of large dimensions, showing how steam-tight joints at the ends are obtained with freedom for expansion. (20.)

53. Give sketches of an arrangement of rope gearing by means of which the power of an engine, fixed on the ground floor of a mill, may be transmitted to the lines of shafting in the various rooms of the mill. State what velocity you would give to the rope, and what considerations would guide you in determining the sizes of the pulleys used. (25.)

54. Give sketches showing the construction of a high-pressure hydraulic accumulator. Explain its object, and mention several uses to which it may be put. Discuss the relative advantages of water and air as a medium for transmitting power. (25.)

55. Give some examples of work for which milling machi are especially suited. State and explain any spe advantages due to this method of shaping material. (20.)

56. With the aid of sketches describe the construction a explain the action of any good form of steam trap. (20.)

SUBJECT II. MACHINE CONSTRUCTION AN DRAWING.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at home. The drawings, &c., are to be sent by post to the Secretary, Science and Art Department, on or before the 18th of June. They need not be prepaid. The drawings should be as fully detailed as possible, and carefully dimensioned. Some marks will be allowed for inking-in and colouring, but more credit will be attached to good proportion and fulness of detail.

The subject for design is a cylindrical internally-fired marine boiler. It is required to generate sufficient steam of 120 lbs. pressure per square inch, with ordinary convection draught, to develop 600 H.P. in an economical engine.

The diameter of the boiler is to be 12′ 4″ and its length 9′ 6″.

(*a*.) Give calculations for the thickness of the plates of shell and furnace, and for the efficiency of the longitudinal joints:

also for areas of fire-grate, tube surface, flue section, and volume of steam room:

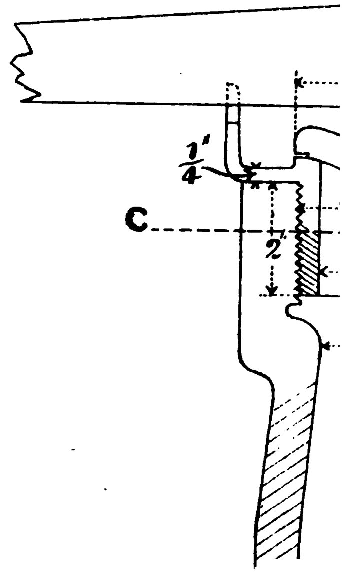
and for strength of stays and stay-tubes.

State the thickness and quality of the material of all the plates used.

(*b*.) Draw a longitudinal sectional elevation of the boiler showing normal water level.

(*c*.) Draw a transverse view, half in section.

The complete detail of the construction of the boiler is required, including the manner of working the joints of all the plates, the attachments of the stays and stay-


1'/4
C
2'

Spring $3\frac{1}{2}''$ outside diam,
of $\frac{1}{2}''$ round steel, pitch
of coils $\frac{3}{4}''$.

Spring need not be shown
in other views

tubes, the position and construction of the man-hole and other doors, and the grate and furnace fittings.

If preferred, some of these details may be shown in separate sketches.

(*d.*) Design on a separate drawing the safety valves suitable for this boiler, giving the calculations for their area, and for the strength and flexibility of the springs.

The other boiler mountings are not required.

The following voucher must be signed and returned with the worked drawings:—

I, ____

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Machine Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed)________________________

No.________

The above number must be quoted on each separate sheet of drawings worked by you.

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary or the Advanced or the Honours paper, but you must confine yourself to one of them.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

All drawings must show a correct knowledge of construction. Neat and accurate drawing to scale is required. Where only sketches are asked for the proportions must be approximately correct, though extreme accuracy, as in drawings to scale, is not necessary. The drawings may be left in pencil, provided they are distinct and neat. No extra marks will be allowed for inking in.

You are to confine your answers *strictly* to the questions proposed.

Put the number of the question before your answer.

Answers in writing must be as short and clearly stated as possible, and close to any figures to which they may refer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

Questions marked (*) have accompanying diagrams.

The Examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt seven* questions.

---

*1. Plans of two successive courses of a brick wall built in single Flemish bond.
Draw to a scale of $\frac{1}{12}$, showing the arrangement of the bricks. (11.)

*2. Elevation of part of the end of a stone wall.
Draw, to a scale of 2′ to an inch, showing at A squared rubble built up to courses, and at B block-in-course work, with plain ashlar quoins to both. (11.)

*3. Plan of the joint between a trimmer and a trimming joist.
Give a vertical section through A—A, to a scale of $\frac{1}{8}$, and show which is the trimmer. (11.)

*4. Cross section through a roof gutter behind a brick parapet.
Draw, to a scale of $\frac{3}{4}$″ to a foot, adding the bricks, slate boarding and tilting fillet, lead gutter and flashing. (11.)

5. Give sketches explaining the following terms in Carpenter's work:—
Plain fished joint—cogged joint—stump tenon. (12.)

*6. Vertical section through the footings of an external wall of a brick dwelling-house, the brickwork resting on the soil.
Draw, to a scale of $\frac{1}{2}$″ to a foot, making any alteration to the footings you think necessary, and showing the bricks laid in English bond. Nothing but brickwork to be shown. (12.)

*7. Line diagram of an iron roof truss.

Give, to a scale of ⅓, a detailed drawing of the joint at A, the struts being of angle iron, 3″ × 3″ × ⅜″, the tie-rod 1″ diameter, and the king-rod ¾″ diameter. (12.)

*8. Section through the eaves of a roof.

Draw, to a scale of 1″ to a foot, adding 1″ slate boarding covered with Countess slates, 20″ × 10″, laid to a 3″ lap, and centre nailed. The slating to show 4 margins. The thickness of the slates may be exaggerated to show the details distinctly. (13.)

9. Show, by a section ½ full size, how an iron bar, 1¼″ diameter, would be leaded into a block of stone.

Give sketches showing the difference between a joggle and a doweled joint in masonry. (13.)

10. Draw, to a scale of 1″ to a foot, the end of a floor joist 9″ deep, notched on to a 4″ × 3″ wall plate carried on brick corbeling, the wall being 14″ thick. The section of the wall to show the method of corbeling out the bricks. (13.)

*11. Elevation of a trussed partition between two rooms.

Draw, to a scale of 1/24, the portion to the left of the line A—A, showing the following details, and how it is supported, as well as any ironwork you may consider necessary:—

Head	4½″	× 6″
Sill..................	4½	× 4
Quarters or studs......	4½	× 2
Door studs	4½	× 4
Braces	4½	× 3
Nogging pieces (one row)	4½	× 2

(14.)

12. Give, to a scale of ¾″ to a foot, sections, at right angles to the direction of the floor boards, showing the difference between a double and a framed floor.

The double floor to be finished with 1½″ rebated boards, and the framed floor with 1½″ battens, rebated and filleted.

Their names to be written against the different members. (15.)

13. Draw, to a scale of ¼, a horizontal section through a window jamb in a 14″ wall, showing the details of a cased frame for 2″ double hung, moulded, sashes.

Give the section of the sash style, and write their names and dimensions against the different members of the frame. (16.)

*14. Front elevation of a framed and braced door with 6" styles, 7" top rail, 9" bottom rail, 10" lock rail, and 6" braces, and filled in with 5" battens.

Draw, to a scale of $\frac{1}{18}$, showing by dotted lines the members at the back of the door. (16.)

Second Stage or Advanced Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions.

21. What is the silver grain or felt, in oak, due to?

Give sketches showing the difference between the appearance of the cross-section of an oak and a pine log. (12.)

22. In Portland stone explain the difference between what is known as "roach" and "base bed."

State in general terms the purposes for which they are most suitable. (12.)

23. The struts of an iron roof are to be formed of bar-iron 3" × $\frac{3}{8}$".

Give an elevation, to a scale of $1\frac{1}{2}$" to a foot, of one of the struts, $3\frac{1}{2}$ ft. long; and any other details necessary to explain its construction. (12.)

*24. Elevation of a beam fixed at one end and loaded at the other to its limit of safety.

Supposing the load were shifted to a point 2 feet from the support, what additional weight, in the shape of an uniform load, could be added to the beam without exceeding its limit of safety? (14.)

*25. Plan of two successive courses of a brick chimney shaft built in ordinary chimney or stretcher bond.

Draw, to a scale of $\frac{1}{12}$, showing how the bricks are laid, and give the name by which the partition between the flues is known. (14.)

*26. A line diagram of an iron roof truss.

Draw, to twice the scale, showing by single lines the members in tension, and by double lines those in compression.

Give a line diagram of a timber truss for the same span. (14.)

*27. Section of part of a double floor.

Draw, to a scale of $\frac{3}{4}$" to a foot, adding sound boarding and pugging, a wooden binder 12" × 8", ceiling joists 3" × 2", and a lath and plaster ceiling. (16.)

*28. Section of the base of a stone wall, resting on a concrete foundation.

Draw, to a scale of $\frac{1}{24}$, showing rubble work built up to courses, and making any alteration you think necessary. (16.)

29. Draw, to a scale of $\frac{1}{6}$, a cross-section through four 3″ × 2″ rafters of an Italian corrugated zinc roof, showing the zinc and how it is secured. (16.)

*30. Plan of a slate roof and chimney shaft.

Draw, to a scale of $\frac{3}{4}$″ to a foot, a vertical section through A—A, showing how the rafters would be trimmed round the shaft, and how the lead guttering and flashings would be fixed. (16.)

*31. Cross section showing the upper flange of a plate girder, with $\frac{1}{2}$″ flange plates, $\frac{1}{4}$″ web, and 4″ × 4″ × $\frac{1}{2}$″ angle irons.

Draw to a scale of $\frac{1}{8}$, adding $\frac{3}{4}$″ rivets where necessary.

Also give a side elevation of same, showing the joints of the flange plates grouped between two $\frac{1}{2}$″ covers 3′ 4″ long; the rivets to have a 4″ pitch. (18.)

32. Give plans showing the difference between an open newel stair and a geometrical stair, the distance from floor to floor being 10 feet.

Show a quarter space resting place to the first, and a half space to the last.

Give a section, half full size, of a suitable handrail with an iron core. (18.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions.

41. Explain the meaning of the "Limit of Elasticity" of a metal. In wrought iron, about what ratio does the limit of elasticity bear to its ultimate strength? (8.)

42. Supposing you were shown two stacks of timber in balk, one being Riga, and the other Dantzic fir, how would you know one from the other, from the appearance of the timber alone, apart from any marks on it? (8.)

43. What are the characteristics of good slates?

Mention any simple tests by which you could jud their quality.

Give the names and dimensions of two sizes of in common use for roofing purposes. (

44. State what different classes of limestone are used building purposes, and the kind of work for which are most suitable. (

45. Give sketches of a 3-light window in each of the follo styles of architecture:—Decorated, Flamboyant, Geometrical, and state the periods during which flourished. (8

46. Draw, to a scale of $\frac{1}{6}$, a fully dimensioned cross sectio the centre of a plate girder 2 feet deep, to carry a form dead load of 40 tons over a 30 feet span. rivets to be $\frac{3}{4}''$. All necessary calculations to be give

Show by a diagram how the shearing stress will distributed over the girder. (8.)

47. Give sketches showing the construction of two differe kinds of fireproof floors, suitable for a store of a wid necessitating the use of columns. (8.)

48. Describe, with explanatory sketches, how you would la out the drains on an estate, and how you would connec the same with the houses, with a view to thorough sanitary efficiency. (8.)

49. Draw a line diagram of an iron roof truss for a goods shed, 40 feet wide.

Give the approximate dimensions of the various sections used, and working drawings, $\frac{1}{4}$ full size, of the different types of joints employed. (10.)

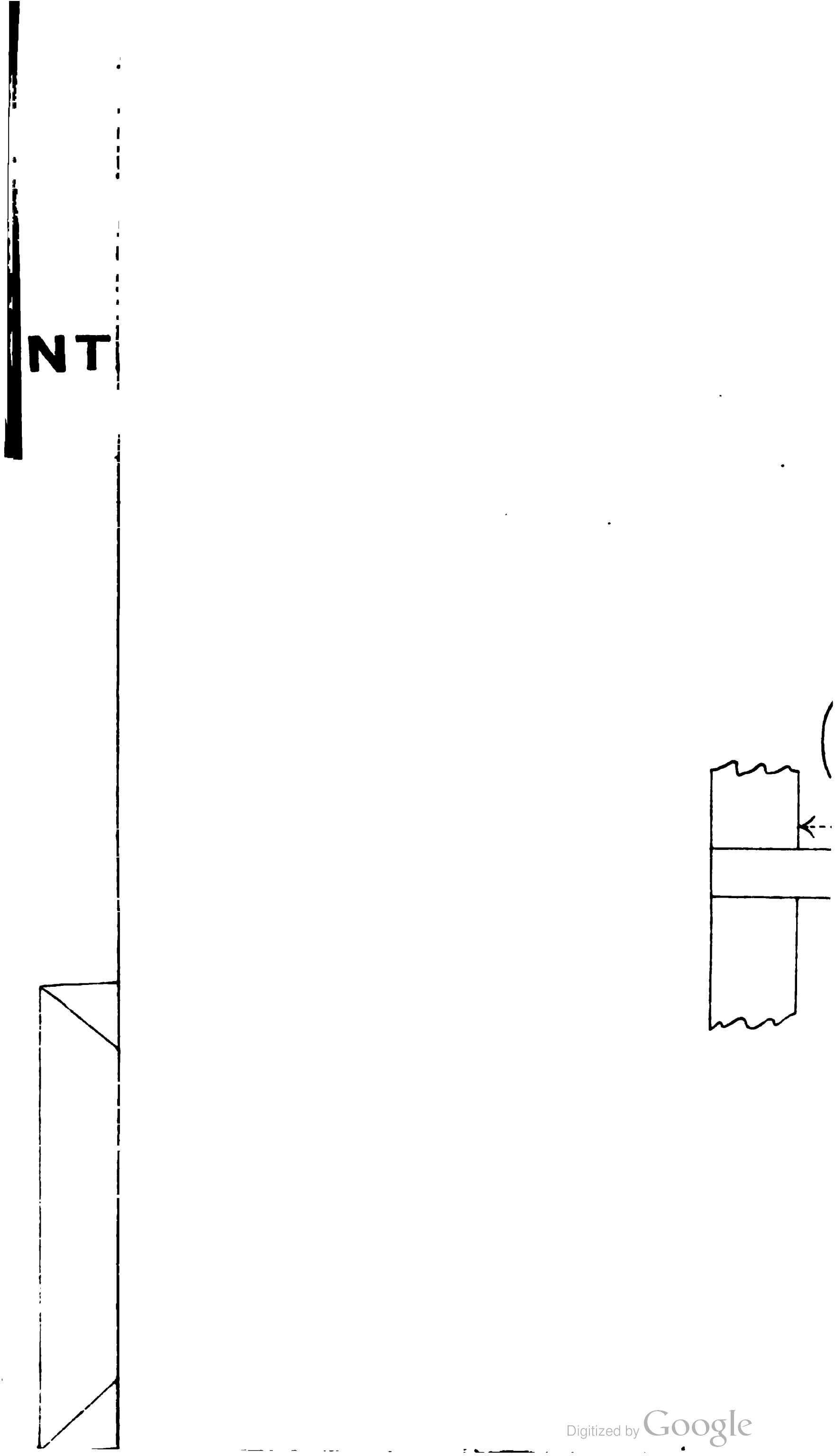
50. In building a dwelling-house with 16″ hollow brick walls, would you place the 4½″ skin on the outside or inside?

State the reasons for and against each method.

Taking an ordinary window opening with a gauged straight arch, show by sketches how you would finish off the brickwork around it, so as to guard against the penetration of rain. (10.)

51. A conservatory is to be glazed with 26 oz. sheet glass.

Give full size sections showing at least two different methods of procuring a watertight roof without the use of putty; not omitting the horizontal joints. (10.)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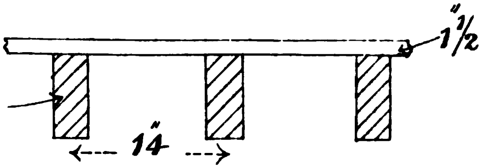


(31)

52. The drawing-room, 16′ × 17′ × 10′, in an ordinary red brick dwelling, is on the ground floor. At one end there is a 3 feet window opening in an 18″ wall, which is to be opened out to a width of 8 feet, to form a bay window 4 feet deep. There is a bedroom window directly over the drawing-room window.

Give, to a scale of 8 feet to an inch, a plan, elevation, and section of the proposed addition. (10.)

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at his own home. The drawings are to be sent by post to the Secretary, Science and Art Department, South Kensington, on or before the 18th of June. They need not be prepaid.

A design is required for a building, in a country village, to contain two rooms about 25′ × 45′, one for use as an adult night school, and the other as a recreation room and library; also an office for the librarian, and a quarter comprising three bedrooms, a sitting-room, kitchen, and offices. The school and recreation room to be capable of being opened up into one large room, when required for special purposes.

The site has a 90 feet frontage with a depth of 82 feet; at about 2 feet below the ground level a rather soft bed of clay is met with.

The walls are to be of coursed rubble with an inner lining of brick.

All the work must be sound and good, the rooms conveniently arranged, and all sanitary requirements carefully attended to.

Plans and elevations to be drawn to a scale of 8 feet to an inch, sections to twice the scale of the plans, and enlarged details to be given as may be required. A small site plan to be given, showing positions of any out-offices.

The drawings must be fully dimensioned, and sufficiently complete to allow of accurate bills of quantities being taken out from them, with the exception of out-buildings, which need only be shown on the general plan.

The approximate cost of the block, ascertained by cubing out the contents, to be stated, and a short description given of the materials proposed to be employed, and of any points requiring special explanation.

The following voucher must be signed and returned with the worked drawings:—

I, ____

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Building Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed)____________________________

No. __________

The above number must be quoted on each separate sheet of drawings worked by you.

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them. Sketches, required to be made to *scale*, *must be inked in with drawing pen.*

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt ten* questions.

You must *attempt No.* 21. Two of the remaining questions may be selected from the Calculations; **and the rest from one, but not from both, of the sections of Practical Shipbuilding.**

PRACTICAL SHIPBUILDING.—SECTION I.

WOOD AND COMPOSITE SHIPS.

1. **How would you trim a piece of keel? At what stage of the work would you complete the cutting out of the rabbets for the garboard strakes? (10.)**
2. **What is a "futtock?" How would you side and mould one? (12.)**
3. **The floors and futtocks of one frame of a small vessel are trimmed, how should they be secured together so that the frame may be hoisted into position upon the blocks? (8.)**
4. **Distinguish between "chain" bolting and "frame" bolting. Usually, chain and frame bolts are of square iron, give the reason for using this form of iron. (8.)**
5. **Show by a rough sketch the method usually adopted in scarphing the stem of a wood ship to the foremost piece of keel. (8.)**
6. **How would you take an account of—**
   (*a.*) The correct length of a wood beam;
   (*b.*) The bevellings of its ends? (12.)
7. **How are the frame angles of a composite ship bent to form and bevelled? (8.)**
8. **Explain with a rough sketch how the frame bar, reverse frame bar, and floor plate are connected together in a composite ship, and shew the riveting. (8.)**

9. How would you fit, and secure in place, a piece of wood bilge keel in a composite ship? (8.)

10. The bottom planking of a composite ship is in two thicknesses. Describe the work to be done in "fastening" each thickness to ensure efficient workmanship. (12.)

PRACTICAL SHIPBUILDING.—SECTION II.

IRON AND STEEL SHIPS.

11. Mention the different parts which form an ordinary transverse frame in an iron or a steel ship. (6.)

12. Referring to question No. 11, explain how far each part extends, and show how the different parts are riveted together. (8.)

13. Where are frame angle bars usually butted? How are they secured at the butts? (8.)

14. What is the difference between a flat keel and a side-bar keel? Show in each case how the butts would be connected and fastened together. (10.)

15. Why is it important that care should be taken in the proper shoring and ribbanding of the frames? If any frame does not conform to the curves of the ribbands, how would you attempt to remedy the evil? (8.)

16. Show by a sectional sketch the form of stem in—
    (*a*.) A large armour clad;
    (*b*.) A small mercantile iron or steel vessel. (8.)

17. Referring to question No. 16, show how the bottom plating would be fastened to the stem in each case. (8.)

18. Two pieces of a large iron stem are to be connected by a scarph and through iron rivets. How would you prepare the holes and proceed with the riveting of the scarph to ensure good workmanship? (12.)

19. Explain how the work of framing a mercantile ship of the ordinary type is proceeded with. (12.)

20. Briefly explain the work in connection with the "plating" of the bottom of an iron or a steel ship. (12.)

DRAWING.

21. What does sketch No. 21 represent? It is on a scale of ⅛" to 1', enlarge it to a scale of ¼" to 1', and show upon it a station 4' 9" abaft F.P.; and a water-line 9' 6" above keel. (14.)

CALCULATIONS.

22. The total area of the deck plan of a vessel is 4,500 square feet, what would be the surface of deck plank to be worked if there are—

4 hatchways, each 4′ × 2½′
2 do. do. 10′ × 6′

and two circular skylights, each 4 feet in diameter, over which no plank is to be laid? (6.)

23. Write down and explain Simpson's 2nd Rule for finding the area of a plane surface.

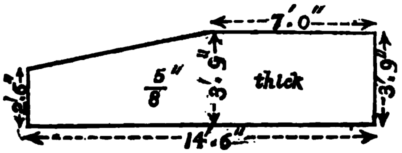
The "half" ordinates of the water-plane of a vessel in feet are respectively, commencing from abaft—

2, 6·5, 9·3, 10·7, 11, 11, 10, 7·4, 3·6, and ·2

and the common interval between them is 15 feet. Find the area of the plane in square feet. (10.)

24. A piece of African oak keelson is 24′ × 12″ × 10″, what is its weight? (6.)

25. A steel plate is of the form and dimensions shown, what is its weight?



(6.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt twelve* questions.

You must attempt No. 54. The remaining questions may be selected from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

31. Show by a rough sketch the method usually adopted in scarphing the stem of a wood ship to the foremost piece of keel; and state why it is important that the stem should be converted from timber of the necessary curvature. (6.)

32. How are fillings between the frames of a wood ship usually fitted and caulked? Why are such fillings worked? (6.)

33. At what stage of the work and for what reasons would you proceed with the chain bolting of the wood frames? (4.)

34. What is a cant floor? How would you trim one? (8.)

35. Mention the different assemblages of inside plank worked on the frames of wood ships, and point out in what cases their value as longitudinal ties is of minor importance. (6.)

36. What are the general requirements of Lloyd's Register for floor plates in composite vessels? (6.)

37. Sketch roughly a method of connecting the flat keel plate and the vertical keelson with the wood stem in a composite vessel. (6.)

38. Sketch roughly a portion of the transverse framing extending from the middle line to the water line of—

(1.) A mercantile composite vessel.
(2.) A recent type of war composite vessel.

(8.)

39. How would you trim, and secure in place, a piece of wood bilge keel in a composite vessel? (8.)

Iron and Steel Ships.

40. Describe the tests to which steel angle bars are subjected to ascertain if they are fit for use. (6.)

41. How would you adjust and prove the frames, reverse frames, and floor plates of a mercantile iron or steel vessel of the ordinary type before riveting them together? (6.)

42. Show by a rough sketch, and briefly describe, an arrangement of skid blocks which is frequently used to facilitate the erection of the frames upon the permanent blocks. (6.)

43. Explain how the work of framing a mercantile ship of the ordinary type is proceeded with. (8.)

44. Sketch roughly an iron or a steel stern-post of a screw ship, showing how it is connected with and fastened to the keel. (6.)

45. Why are the bilge strakes frequently worked thicker than the adjacent strakes of plating?

In what types of transverse framing of mercantile and war ships, and for what reasons, should particular attention be given to the strength of the plating at the turn of the bilge? (6.)

46. Show a good disposition of butts of bottom plating. State dimensions of plates and spacing of frames. Show on a large scale the rivets in a butt, an edge, and at a frame station. (8.)

47. Indications of straining at some of the butts of the outer bottom plating of long vessels are sometimes found when such vessels are docked.

In what parts of such plating, and for what reasons, would you expect to find these indications? Explain with a rough sketch a simple and inexpensive method of stiffening such butts. (8.)

48. What principles ought to govern the construction of water-tight bulkheads, so that the greatest stiffness and strength to resist water pressure may be obtained with the least weight of material? (6.)

LAYING OFF.

49. Define body plan, sheer plan, half-breadth plan, and state briefly what uses are made of them. (6.)

50. The stem of a composite vessel has both rake and taper; how would you obtain approximately the centre of rabbet? (6.)

51. How would you obtain and fair on the Mould Loft floor the parts of the frames in wake of the screw shafts of a twin screw ship? (8.)

52. How are the edges of the outer bottom plates obtained and faired on the Mould Loft floor?

Show roughly in the body plan the general shape of the plate edges. (8.)

53. How would you lay off the moulding edge of a cant frame in the Body plan? (6.)

DRAWING.

54. Sketch No. 54 is on a scale of $\frac{1}{2}''$ to 1′. Draw it on an inch scale, showing the beam knee; and the riveting in the frame angles and beam knee. (12.)

CALCULATIONS.

55. The half-ordinates of the load-water plane of a vessel in feet *commencing from abaft*, are respectively $2\frac{1}{2}$; 8; $11\frac{1}{2}$; $13\frac{1}{2}$; $13\frac{3}{4}$; $12\frac{1}{2}$; $9\frac{1}{4}$; $4\frac{1}{2}$; and $\frac{1}{4}$; the common interval between the ordinates being 16 feet; find—

(1.) The area of the plane.

(2.) The longitudinal position of its C.G. *abaft the foremost* ordinate. (8.)

56. Write down and explain Simpson's 2nd Rule for finding the area of a plane surface.

The half ordinates of a water plane of a vessel in feet are respectively, commencing from abaft:—2; 6·5; 9·3; 10·7; 11; 11; 10; 7·4; 3·6; and ·2, and the common interval is 14 feet. Find the area of the plane in sq. ft. (8.)

57. Having given the dimensions on the load-water plane, state the practical rules by which a close approximation may be made to the weight which must be added, or removed, to change the mean draught of water one inch, in three different types of vessels. (6.)

58. Define displacement. The areas of the vertical transverse sections of a ship up to the load-water plane in sq. ft. are respectively 25; 100; 145; 250; 470; 290; 220; 165; and 30; and the common interval between them is 20 ft. The displacement in tons before the foremost section is 5, and abaft the aftermost section is 6. Find the load displacement of the ship in tons and in c. ft. (6.)

59. Write down and explain the formula giving the height of the transverse metacentre above the centre of buoyancy.

State clearly the use that can be made of this height by the naval architect when he knows it for any particular vessel. (6.)

60. What principle should be followed in arranging the fastenings in a stringer plate at the beams and at the butts?

A stringer plate is 42″ × $\frac{1}{2}$″; show the riveting in a beam and at a butt, stating size and pitches of rivets, and show that the arrangement you give is a good one. (8.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt fourteen* questions. You may select these from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

71. Give a rough sketch of—

(1) a plain scarph,
(2) a hook do.
(3) a tabled do.

and state where each is commonly used. (6.)

72. Where and for what reasons have cant floors been used? How would you side and mould a cant floor? (8.)

73. Mention the different assemblages of inside plank worked on the frames of wood ships, stating where they are fitted. Point out in what cases their value as longitudinal ties is of minor importance. (6.)

74. How would you trim a piece of stem for a composite ship? (6.

75. Sketch roughly a midship section of a composite vessel, and mark upon it the names of the different parts. (8.)

76. Referring to question No. 75, give the sizes of each of the principal parts in any vessel with which you are acquainted, stating the dimensions of the vessel you take. (6.)

IRON AND STEEL SHIPS.

77. How are Z bar frames bevelled and bent to their proper curvature? (6.)

78. Show by rough sketches a method which has been adopted in the framing of ships where the transverse frames are alternately continuous and intercostal. (8.)

79. Referring to question No. 78, give the reasons for adopting such an arrangement. (6.)

80. A portion of the framing of a steel ship is in place and ready to receive the bottom plates. Describe the work in connection with the preparation of the bottom plates and fitting them to the frames. (8.)

81. Give the reasons for the small differences in the thickness of outer bottom plates in ships varying greatly in size.
In what parts of ships and for what reasons is the outer plating doubled? (6.)

82. Explain how the bottom plating is fitted and secured to the stern-post—
(*a.*) In a small mercantile screw vessel.
(*b.*) In a large armour-clad ship. (6.)

83. What is the chief value of diagonal deck tie plates?
What are the requirements of Lloyd's Register for such ties? (6.)

84. Sketch a disposition of deck plating and show the fastenings in edges, butts, and beams where the plating is in one thickness. (6.)

LAYING OFF.

85. The traces of a plane and the projections of a point not in the plane being given in the sheer and half-breadth plans, show how a plane may be drawn which shall contain the point and be parallel to the given plane. (6.)

86. How would you obtain and fair on the Mould Loft floor the parts of the frames in wake of the screw shafts of a twin screw ship? (6.)

87. How would you lay off the moulding and bevelling edges of an ordinary harpin, and obtain the bevellings? (6.)

88. How are the lines for the inner bottom plate edges of a double-bottomed ship obtained and faired? (6.)

89. A steel mast is to have considerable rake and taper. How would you obtain an account of all its parts in order that they may be demanded from the manufacturer? (8.)

CALCULATIONS.

90. The "tons per inch" of five equi-distant water planes of a ship are respectively 9·8; 8·8; 7·6; 5·9; and 3·4; the water planes being 2¼ feet apart.

Below the lowest of the planes mentioned is an appendage of 60 tons.

Calculate the displacement in tons up to each of the water planes. (8.)

91. Referring to question No 90, construct the curve of displacement on a scale of ¾″ per foot of draught, and ¾″ per 100 tons of displacement, the lowest water plane mentioned being 3 feet above the keel. (6.)

92. Obtain the expression for the height of the transverse metacentre above the centre of buoyancy.

The displacement of a vessel is 400 tons, and the transverse metacentre is 5¾ feet above the centre of buoyancy. A weight of 12 tons, already on board, is moved 8 feet across the deck, find the inclination of the vessel to the upright, the C.G. of the vessel being 3 feet above the C.B.

$$\tan 4^\circ = 0{\cdot}0699$$
$$\tan 5^\circ = 0{\cdot}0875$$
$$\tan 6^\circ = 0{\cdot}1051$$

(6.)

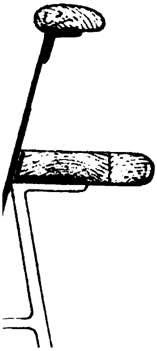
SUBJECT IV

18. 2/87

L.

.– ADVANCED STAGE.

No. 54.



93. What is meant by "moment to change trim"? Write down and explain the expression which gives the moment to alter trim one inch.

Suppose a weight of moderate amount to be put on board a ship, where must it be placed so that the ship shall be bodily deeper in the water without change of trim? Give reasons for your answer. (6.)

94. A transverse iron watertight bulkhead is worked in a ship at a station whose semi-ordinates are (commencing from below) 6; 9; $10\frac{1}{2}$; $11\frac{1}{2}$; $12\frac{1}{2}$; $12\frac{1}{2}$; and 12 feet respectively, the common interval being 2 feet.

Find the weight of the bulkhead, the following particulars being given:—

Plates, lap jointed, lap butted, single riveted .... $\left\{\begin{array}{l}\frac{3}{8}'' \text{ for lower 5 feet.}\\ \frac{5}{16}'' \text{ for upper 7 feet.}\end{array}\right.$

Angle bar stiffeners 24" apart on one side of bulkhead .... $\}\ 2\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{5}{16}''$.

(8.)

95. Distinguish between hogging and sagging strains. A vessel has an excess of weight amidships, to what conclusion would you generally arrive as to the strains produced?

Point out, illustrating your remarks by a simple example, that your general conclusion might not be correct in some cases. (8.)

96. What are the causes which influence the *forms* of curves of stability?

Give an example of such curves for—

(1.) A low freeboard mastless armour-clad.
(2.) A high freeboard cruizer with large sail spread.

(6.)

97. Explain how lifeboats are designed to automatically right themselves when capsized, and to free themselves of water when swamped. (6.)

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidates at their own homes. The drawing and calculations are to be sent by post to the Secretary, Science and Art Department, South Kensington, on or before the 18*th of June. They need not be prepaid.*

101. From the particulars given on sketch No. 101, *complete* building draught on a scale of ¼ inch to and calculate :—

(1.) The displacement in tons up to water li 3½, 5½, 7½, 9½, 11½, and 13½ feet respectivel

(2.) The vertical and longitudinal positions centre of buoyany of the vessel when float the draught 13 feet forward, 14 feet aft.

The following voucher must be signed and returned wi worked drawing :—

I, ______________________________________

hereby certify on my honour that the drawing and calcul sent in by me, for the Honours Examination in Naval Arc ture, have been done wholly by me, and without assistance any person.

(Signed)________________________

No._______

The above number must be quoted on each separate shee drawings, &c., worked by you.

SUBJECT V. PURE MATHEMATICS, STAGES 1, 2, & 3.

EXAMINERS, REV. J. F. TWISDEN, M.A., AND
A. R. WILLIS, ESQ., M.A., D.SC.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You are permitted to answer questions from the First Stage, or from the Second Stage, or from the Third Stage, or from the Honours Paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Every page of the paper supplied for the answers may be used.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

All the work by which a result is obtained must be clearly shown *in immediate connexion with the question.* No credit will be allowed for any result, however correct it may be, unless the work be shown, so as to enable the Examiners to satisfy themselves that the candidate has understood the question, and to see by what process the result has been obtained.

Anything which you do not wish the Examiners to notice should be crossed out with the pen.

A table of logarithms must NOT be used in working these papers. All the logarithms needed will be found on the accompanying paper.

Unless you expressly state the contrary, it will be assumed that you have read GEOMETRY *in Euclid, and you will be expected to follow Euclid's sequence. Otherwise, you must state what text book you have used in geometry.*

The examination in this subject lasts for three and a half hours.

Mathematics, First Stage.

INSTRUCTIONS.

Read the General Instructions above.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

Section A.

1. Multiply $1 - \dfrac{\frac{3}{10}}{(\frac{1}{2} + \frac{1}{5})}$, by $1 - \dfrac{\frac{1}{10}}{\frac{1}{4} - \frac{1}{10} + \frac{1}{25}}$.

   Divide $0{\cdot}2 \times 0{\cdot}3 \div 0{\cdot}00012$ by $\left(5{\cdot}719 \times \dfrac{1}{1{\cdot}9}\right) + (0{\cdot}3 \times 1{\cdot}2 \times 9)$.

   (10.)

2. Extract the square roots of 0·51 and 0·051 to four places of decimals. (8.)

3. Subtract 0·0625 of £113 16*s*. 8*d*. from $\frac{2}{3}\frac{3}{4}$ of £50 5*s*. 6*d*., and find the number by which the result must be multiplied to produce £985 11*s*. 6*d*. (10.)

4. Find the amount of £512 in $1\frac{1}{2}$ years at $2\frac{1}{2}$ per cent. per annum: first, at simple interest; secondly, at compound interest, supposing that the interest due is added at the end of each half-year. (Fractions of a penny may be neglected.) (8.)

5. Given that a mètre is 3·3708 inches longer than a yard, find which is greater, 10 square mètres, or 12 square yards; and express the difference between these areas as a decimal of a square mètre correct to three places. (10.)

6. A man pays away half his money to A, a third of what he has left to B, and a fifth part of what he still has left to C; if after these payments he has 12*s*. 8*d*. left, how much had he at first? (10.)

Section B.

7. Two triangles are on the same base and on the same side of it, and the two sides terminated in one extremity of the base are equal, then the two sides terminated in the other extremity of the base are unequal. Prove this when the vertex of the one triangle falls within the other.

If, within the triangle ABC, there be such a point D that AC and AD are equal, show that AB is longer than AC. (12.)

8. In the triangles ABC, DEF, the sides AB, BC, CA are respectively equal to DE, EF, FD; show that the angle A is equal to the angle D.

If a quadrilateral has its opposite sides equal, show that its opposite angles are equal. (10.)

9. Show how to draw through a given point a straight line parallel to a given straight line.

When are two straight lines said to be parallel?

State the property of parallel straight lines assumed in the solution of the above problem. (10.)

10. Show that if a side of a triangle is produced, the exterior angle thus formed is equal to the two interior and opposite angles.

ABC is a triangle having the sides AB, AC equal; in AB take any point D, and produce CA to E, making AE equal to AD; show that ED produced cuts BC at right angles. (12.)

11. If a parallelogram and a triangle are on the same base and between the same parallels, show that the parallelogram is double of the triangle.

AB is the base of a given parallelogram; show how to construct a rhombus equal in area to the parallelogram, and having AB as a diagonal. (14.)

12. Given two straight lines AB, AC, show how to describe an equilateral triangle DEF, whose sides are of a given length, so that D and E may lie in AB, and F in AC.

Under what circumstances will D and E lie on opposite sides of A? (14.)

Section C.

13. If $x = 2$ and $y = -\frac{1}{2}$, find the numerical values of $3(x + y) - 2(x - y)$, x^4y^6, x^3y^5, and $\frac{x^3 - y^3}{x - y}$. (12.)

14. Subtract $6x + 1 - 2(x + 5y) - \{2 - (x + 2y - 1)\}$ from $2(2 - y) - 7x - 2\{1 - 3y + 6(y - x)\}$. (10.)

15. Simplify $2x^2 - 3\left(\frac{y^2}{2} - x^2\right) - \frac{1}{2}\{4x^2 - \frac{1}{2}(24x^2 + 5y^2)\}$ and divide the simplified expression by $x + \frac{y}{6}$. (12.)

16. Find the greatest common measure of $x^3 + 3x^2 - 25x + 21$ and $2x^3 - 9x^2 + 10x - 3$, and write down these expressions in factors. (12.)

17. Solve the equations—

(*a.*) $(2x - 1)(3x - 2) - (x - 1)(x + 1) = 5(x - 1)^2$.

(*b.*) $0{\cdot}5x - 0{\cdot}6y = 1{\cdot}38$.

$$\frac{x}{3} + \frac{y}{0{\cdot}5} = 2.$$ (14.)

18. Divide 279 into two parts such that one-third of the first part is less by 15 than one-fifth of the second part. (14.)

Mathematics, Second Stage.

INSTRUCTIONS.

Read the General Instructions on the first page.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

Section A.

21. Find the value of $\sqrt{\left(\frac{\sqrt{5} - 2}{\sqrt{5} + 2}\right)}$ to three places of decimals.

Show, without extracting roots, that $\sqrt{17} + \sqrt{19}$ is less than $6\sqrt{2}$.] (15.)

22. Find the product of $\frac{a}{4}+\frac{\sqrt{(ab)}}{3}+\frac{b}{9}$ and $\frac{\sqrt{a}}{2}-\frac{\sqrt{b}}{3}$, and find the value of the product when $a = 12$ and $b = 18$. (15.)

23. Solve completely the equations :—

$$(a.)\quad x^2 - 2x\sqrt{3} + 2 = 0.$$

$$(b.)\quad x^2 + \frac{9}{x^2} - 4\left(x + \frac{3}{x}\right) - 6 = 0.$$

$$(c.)\quad \begin{aligned} x^2 - 2x + y^2 - 2y &= 14. \\ xy &= 5. \end{aligned}$$

(25.)

24. A cistern is furnished with three taps A, B, C, such that A and B running together can fill the cistern in 6 minutes, B and C in $8\frac{4}{7}$ minutes, and A and C in $6\frac{2}{3}$ minutes. If A alone be turned on for 2 minutes, and then B alone for 6 minutes, how long will it take C alone to complete the filling of the cistern? (20.)

25. A person bought a certain number of yards of cloth for £2 10*s.*; if the price had been 10*d.* a yard less he would have obtained 3 yards more for the same money; find how many yards he bought, and the price per yard. (20.)

26. A body is made up partly of brass and partly of iron; if the brazen parts had been iron, and the iron parts brass, its weight would have been $\frac{21}{19}$ths of what it actually is. Given that the weights of equal volumes of brass and iron are as 9 to 7, find how much of the volume is of iron, and how much of brass. (25.)

Section B.

27. Show how to describe a square equal to a given rectilineal figure.

Show how to describe a rectangle equal to a given square and having a perimeter double that of the square. (20.)

28. If a diameter of a circle cuts a chord, which is not a diameter, so as to bisect it, show that it cuts it at right angles.

Show that the bisected line is the shortest chord that can be drawn through the point of bisection. (20.)

29. Show that in equal circles equal arcs are subtended by equal chords.

Let A, B, C, D be four points taken in order on the circumference of a circle, whose centre is O, such that AB is equal to CD; join AC and BD intersecting in P; show that OP produced bisects the arc BC. (25.)

30. Show how to bisect a given arc of a circle.

Take points A, B, C, D, E in order on the circumference of a circle, such that B is midway between A and C, and D midway between C and E. Draw the chord BD intersecting the chords CA and CE in F and G. Show that the angle CFD is equal to the angle CGB. (25).

31. From a point D outside a given circle a line DCA is drawn cutting the circle in C and A, and not passing through the centre, and a line DB touching the circle at the point B; show that the rectangle AD, DC is equal to the square on DB.

A number of circles all pass through two given points M and N; from a point P in MN produced tangents are drawn to the circles; show that the points of contact lie on the circumference of a circle. (25.)

32. A parallelogram is so long that two circles, exterior to each other, can be described in it, so as to touch three sides: a line is drawn to touch both circles, and is terminated by the longer sides; show that the line equals the difference between a long and a short side. (25.)

Section C.

33. Define the characteristic of a logarithm, and show that in common logarithms $\log(N \times 10^n) = n + \log N$. Why would this not be true for logarithms of any base but 10?

Write down log 106·13, log 0·0010613, and find $\log\sqrt{(0{\cdot}02)}$ and $\log(0{\cdot}02)^7$. (20.)

34. Define the cosine of an acute angle, and state what more is required in order to make the definition applicable to an obtuse angle.

Show that $\cos(180^\circ - A) = -\sin(90^\circ + A)$, and write down the numerical values of the sine, cosine and tangent of 45° and 135°. (20.)

35. In a triangle ABC, $a = \sqrt{5}$, $b = 2$, $c = \sqrt{3}$; show that $8\cos A\cos C = 3\cos B$. (25.)

36. Given two sides and the included angle of a triangle, write down a formula for finding the remaining angles by the help of logarithms.

The sides being 237·09 ft. and 130·96 ft., and the included angle 57° 59′, find the remaining angles to the nearest second. (25.)

37. AB is a line 1000 yards long; B is due north of A. At B a distant point P bears 70° E. of North; at A it bears 41° 22′ E. of North; find the distance from A to P. (20.)

38. The summit of a spire is vertically over the middle point of a horizontal square enclosure, whose side is a ft. long; the height of the spire is h ft. above the level of the square. If the shadow of the spire just reaches a corner of the square when the sun has an altitude θ, show that

$$h\sqrt{2} = a \tan \theta.$$

Calculate h having given $a = 1000$ ft., $\theta = 27° \, 29' \, 48''$. (25.)

Mathematics, Third Stage.

INSTRUCTIONS.

Read the General Instructions on the first page.

You must confine your answers entirely to Sections A and B, or to Sections A and C; and you must not answer more than *four* questions in either section.

You must not answer more than eight questions altogether.

The number of marks assigned to each question is given in brackets.

Section A.

41. Simplify—

$$\frac{1}{\{\sqrt{(a+b)}+\sqrt{a}-\sqrt{b}\}^2} + \frac{1}{\{\sqrt{(a+b)}-\sqrt{a}+\sqrt{b}\}^2}$$ (30.)

42. If A, B, C . . . . M, N are in geometrical progression, show that—

$$(A^2 + B^2 + \dots + M^2)(B^2 + C^2 + \dots + N^2) = (AB + BC + \dots + MN)^2.$$ (30.)

43. Find the number of homogeneous products of r dimensions that can be formed of n letters ($a, b, c, \dots$) and their powers.

Show that the number of all the terms in the expansion of $(a + b + c + d)^{12}$ is five times the number of the terms that do not contain some one letter, as d. (40.)

44. Draw two equal straight lines AB, AD, and two other equal straight lines AC, AE, so that the angle BAD may equal the angle CAE. Join BC and DE, and show that the angle between these lines equals BAD. (35.)

45. On the same chord and on the same side of it two arcs of circles are described each greater than a semicircle; show how to draw through one end of the chord a straight line cutting both the arcs and such that its segment between them is the greatest possible. (40.)

46. Two equal circles intersect in A, B; take a point P inside both circles, and with centre A and radius AP describe the circle CDPEF cutting the given circles in points C, D, E, F. Show that CD, and FE, when produced, pass through B. (35.)

Section B.

47. Prove the formula $\cos A = 4\cos^3 \frac{A}{3} - 3\cos \frac{A}{3}$.

If the value of cos A be given, show geometrically that there are in general three different values of $\cos \frac{A}{3}$, and point out all the angles to which they belong. (35.)

48. Eliminate θ and ϕ from the equations—

$$\cos\theta + \cos\phi = a, \qquad \text{cotan}\,\theta + \text{cotan}\,\phi = b,$$

$$\text{cosec}\,\theta + \text{cosec}\,\phi = c. \qquad (35.)$$

49. Show that in any triangle $a = b\cos C + c\cos B$, both when B and C are acute, and when one of them is obtuse.

Show that in any triangle four times the area equals—

$$b^2 \sin 2C + c^2 \sin 2B,$$

and interpret the result geometrically. (35.)

50. In any triangle show that—

$$a^2b^2c^2 (\sin 2A + \sin 2B + \sin 2C) = 32S^3,$$

where S denotes the area of the triangle. (35.)

51. In a triangle ABC join C to any point D in AB; let R and R_1 be the radii of the circles which circumscribe the triangles ACD and BCD respectively; show that $Ra = R_1b$, and that the distance between the centres of the circles is $Rc \div b$.

Explain these results in the case when D is moved up to B. (40.)

52. A, B, C are three consecutive milestones on a straight road, from each of which a distant spire is visible. The spire is observed to bear N.E. at A, due east at B, and 60° E. of S. at C. Find the distance of the spire from A, and the shortest distance of the spire from the road. (40.)

Section C.

53. If a solid angle is contained by three plane angles, show how the several parts of the solid angle may be represented by a spherical triangle. What line drawn in the spherical triangle would represent the inclination of one edge of the solid angle to the plane passing through the other two edges?

Show that any side of a spherical triangle is greater than the difference of the other two sides. (35.)

54. Define the polar triangle of a given spherical triangle, and show that if a triangle (A) is the polar triangle of a given triangle (B), then B is the polar triangle of A. (30.)

55. If A and a are an angle and a side of an equilateral spherical triangle, and A′ and a' an angle and a side of the polar triangle, show that—

$$2\cos\frac{a}{2}\cos\frac{a'}{2} = 1, \text{ and } 2\sin\frac{A}{2}\sin\frac{A'}{2} = 1,$$

and explain the results when a is made indefinitely small. (40.)

56. Establish a formula by which the angles of a right-angled spherical triangle may be found, when the two sides containing the right angle are given.

Given $a = 60°$, $b = 154° 22'$, $C = 90°$, find A and B. (35.)

57. Find the angle B of a spherical triangle in which $A = 88° 52'$, $a = 73° 50'$, and $b = 120°$.

Show that with the given values of A and b, there is only one triangle so long as a lies between 60° and 120°. What would be the case if a were (1) equal to 120°, (2) greater than 120°? (35.)

58. Two points are in latitude 20° S., one is in longitude 80° W., the other is in longitude 150° E.; assuming the earth to be a sphere, find the length of the arc of the great circle, and that of the arc of the parallel of latitude passing through the points. N.B. The answers may be expressed in nautical miles. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.
You may not answer more than ten questions.
The same value is attached to each question.

61. If $x^2 - yz - a^2 = y^2 - zx - b^2 = z^2 - xy - c^2 = 0$, show that—

$$\frac{x}{a^4 - b^2c^2} = \frac{y}{b^4 - c^2a^2} = \frac{z}{c^4 - a^2b^2},$$

and find x, y, z in terms of a, b, c.

62. Find, by algebra, the value of y which gives—

$$y\sqrt{3} + \sqrt{(1 - y^2)}$$

its greatest value.

63. Write down the expansion of a^x in ascending powers of x, and deduce therefrom the expansion of $\log_e(1+y)$ in ascending powers of y.

Show that the Napierian logarithm of the product of

$$(1 + ax)^{\frac{1+ax}{2a}} \text{ and } (1 - ax)^{\frac{1-ax}{2a}} \text{ is equal to}$$

$$\frac{ax^2}{1.2} + \frac{a^3x^4}{3.4} + \frac{a^5x^6}{5.6} + \ldots . \textit{ ad infin.}$$

64. Find the coefficient of x^n in the expansion of $(1 - 2x + x^2)^{-2}$, and hence show that—

$$6\{1 . n + 2(n-1) + 3(n-2) + \ldots . + (n-1) . 2 + n . 1\}$$
$$= n(n+1)(n+2).$$

65. Show which of the following series are convergent and which divergent—

$$(a.)\ 1 + \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{3}} + \frac{1}{\sqrt{4}} + \ldots .$$

$$(b.)\ 1 - \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{3}} - \frac{1}{\sqrt{4}} + \ldots .$$

$$(c.)\ 1 + \frac{1}{3} + \frac{1}{5} + \frac{1}{7} + \ldots .$$

66. ABCD is a quadrilateral whose diagonals are AC and BD; draw AF parallel to BC, cutting BD (produced if necessary) in F, and draw BE parallel to AD, cutting AC (produced if necessary) in E; join EF; show that EF is parallel to CD.

67. AC and BD are fixed diameters at right angles to each other, and P any point on the circumference of the circle ABCD; let PA and BD intersect in E; draw EQ parallel to AC to intersect PB in Q, any of these lines being produced if necessary; show that the locus of Q is a straight line.

68. AB is the diameter and C the middle point of the arc of a semicircle; take D, the middle point of the chord BC; let AD be produced to meet the circumference in E; draw EF perpendicular to BC; show that CF is three times EF.

69. ABC is a triangle whose sides AB and AC are equal; take D and E, the middle points of BC and AB; join AD; through E draw a line at right angles to AB cutting AD in L, and also cutting in F a line drawn from B at right angles to BC; through F draw a line parallel to AC to cut BC in H; join HL; show that HLF is a right angle.

70. Calculate in a decimal form the numerical values of $\sin(\sin 30^c)$ and $(\sin 60^\circ)^{\sin 60^\circ}$.

Find an expression for all the angles which satisfy the equation—

$$\tan^2\theta - (\tan A + \cot A)\tan\theta + 1 = 0.$$

71. If A, B, C, a, b, c are the angles and sides of a plane triangle, show that—

$$\frac{\cot\frac{A}{2} + \cot\frac{B}{2} + \cot\frac{C}{2}}{\cot A + \cot B + \cot C} = \frac{(a+b+c)^2}{a^2+b^2+c^2}.$$

72. Show that $\cot^4\theta$ is equal to the product of the two infinite series—

$$1 + 2\cos^2\theta + 3\cos^4\theta + 4\cos^6\theta + \dots.$$

and $$1 - 2\tan^2\theta + 3\tan^4\theta - 4\tan^6\theta + \dots.$$

Show that $\cot^{-1}(1 + \cot\theta + \cot^2\theta)$ is equal to the sum of the infinite series—

$$\sin\theta \,.\, \frac{\sin\theta}{1} - \sin 2\theta\,\frac{\sin^2\theta}{2} + \sin 3\theta \,.\, \frac{\sin^3\theta}{3} - \&c.$$

73. Express $\cos n\theta$ in a series of descending powers of $\cos\theta$, when n is a positive integer.

Solve the equation $\cos 5\theta + \cos 3\theta + \cos\theta = 0$.

74. Establish the relation which exists between the cosines of the six arcs joining, two and two, any four points on a sphere.

75. If r, r_1, r_2, r_3 are the radii of the inscribed and escribed circles of a spherical triangle, show that—

$$\tan r \tan r_1 \tan r_2 \tan r_3 = \sin s \sin(s-a)\sin(s-b)\sin(s-c).$$

76. If the sides of a spherical triangle are small compared with the radius of the sphere on which it is described, show that, approximately, each angle of the spherical triangle exceeds by one-third of the spherical excess the corresponding angle of the plane triangle, the sides of which are of the same length as the arcs of the spherical triangle.

TABLES FOR THE QUESTIONS.

Logarithms of Numbers.

Number.	Logarithm.
·2	301 0300
10613	025 8382
19609	292 4554
10	4776
36804	565 8950
5	9068
·47942	680 7161
3	7252
86603·	937 5329
88288	945 9016

Natural Sine 70° = 0·93969
√2 = 1·4142
√3 = 1·73205
√5 = 2·23607

Logarithms of Sines.

Angle.		Log. Sin.
°	′	
25	38	9·636 0969
28	38	9·680 5191
	39	7504
58	23	9·930 2226
	24	3004
60	0	9·937 5306
64	21	9·954 9441
	22	5 0047
65	0	9·957 2757
70	0	9·972 9858
73	50	9·982 4774
88	52	9·999 9150

Logarithms of Tangents.

Angle.		Log. Tan.
°	′	
14	1	9·397 3089
	2	8463
27	29	9·716 1682
	30	4767
30	0	9·761 4394
61	0	10·256 2480
	1	5460
64	22	10·318 9079
75	58	10·602 1537
	59	6911

SUBJECT V. PURE MATHEMATICS, STAGES 4 and 5.

EXAMINER, P. T. WRIGLEY, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Fourth Stage, or from the Fifth Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The figures in descriptive geometry should not only be constructed with ruler and compasses, but the construction should in all cases be explained and its accuracy demonstrated.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Fourth Stage.—Subjects: Plane, Solid, and Descriptive Geometry and Geometrical Conics.

INSTRUCTIONS.

You are not permitted to *attempt* more than *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

1. When are four quantities said to be in proportion? Show that the areas of triangles of the same altitude are proportional to their bases.

From any point within a regular polygon of n sides let fall a perpendicular upon each of the sides; show that the sum of these perpendiculars is equal to the radius of the inscribed circle of a regular polygon of the same number of sides as the original polygon, but having a perimeter n times as great. (18.)

2. If the vertical angle of a triangle be bisected, show that the bisector divides the base into segments which have the same ratio as the adjacent sides.

   If the line bisecting the angle BAC of a triangle meet the side BC in D, show how to construct the triangle, having given the lengths of AB, AC, AD. (20.)

3. Show how to inscribe a regular pentagon in a given circle.

   If circles be described, each of which touches a pair of alternate sides of a regular pentagon at the extremities of the intermediate side, show that all such circles have a common point. (18.)

4. If two straight lines be parallel, and one of them be at right angles to a plane, prove that the other is also at right angles to the plane.

   If a triangular pyramid be cut by a plane drawn parallel to two opposite edges, show that the section is a parallelogram. (20.)

5. Show that in a given sphere the surface of a spherical zone cut off by two parallel planes depends only on the distance between the planes.

   If the radius of the circular base of a spherical cap be four-fifths of the radius of the sphere, show that the surface of the cap is one-fifth that of the sphere. (18.)

6. Prove that the plane bisecting any dihedral angle of a given tetrahedron divides the opposite edge into segments which are in the ratio of the areas of the adjacent faces. (18.)

7. Give the projections a, a' of a point equidistant from the vertical and horizontal planes; also of a line which is oblique to both planes, and which intersects the horizontal plane at a given point; take in the vertical plane a third point not on this line: find the traces of the plane which passes through these three points. (16.)

8. Having given the traces of two planes, find the projections of their line of intersection.

   Obtain the angle which one of the planes makes with the horizontal plane; also the angle between the two given planes. (18.)

9. The projections of two points being given, find the traces of the plane which is perpendicular to the line joining these points, and also equidistant from them. (16.)

10. Define a conic section, and distinguish the different species of conic sections.

    Show that in any conic section the tangents at the extremities of a focal chord intersect on the directrix; also that in one species they intersect at a constant angle. (16.)

11. Prove that in an ellipse the normal at any point bisects the angle between the focal distances of that point.

    Show also that tangents at the ends of parallel focal radii intersect on a fixed circle. (18.)

12. Show that the difference between the squares of any two conjugate semi-diameters of a hyperbola is equal to the difference between the squares of the semi-axes.

    If A be the vertex, and P, P′ be points equidistant from A on the same branch PAP′ of a hyperbola, and if lines be drawn through A, P, P′, parallel to each other, meeting one of the asymptotes in R, Q, Q′ respectively; show that PQ, AR, P′Q′ are in continued proportion. (20.)

Fifth Stage.—Subjects: Descriptive Geometry, Spherical Trigonometry, Co-ordinate Geometry of two and of three dimensions.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage Paper.

You are not permitted to *attempt* more than *eight* questions, and may select them from any part of the paper.

The marks assigned to the questions are shown in brackets.

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21. Given the projections of two straight lines which are not in the same plane, draw the projections of the line which cuts each of them at right angles, and construct the actual length of the segment intercepted between the two given lines. (35.)

22. Given the projections of a right cone and of a point external to the cone, determine the traces of a tangent plane passing through the point; also find the projections of the normal at any point of the line of contact. (35.)

23. Establish the fundamental formula which expresses the cosine of an angle of a spherical triangle in terms of the sides.

    If A′, B′ be the middle points of the sides CB, CA of a spherical triangle, prove that

$$\sin^2 A'B' = \sin^2 \frac{c}{2} + \sin^2 \frac{a}{2} \sin^2 \frac{b}{2} \sin^2 C. \qquad (30.)$$

24. State and prove Napier's Analogies.

If ABC be a spherical triangle, right-angled at C, and 2S denote the sum of the angles, show that

$$\cot S = -\tan\frac{a}{2}\tan\frac{b}{2}. \qquad (35.)$$

25. Obtain an expression for the angular radius of the small circle inscribed in a given spherical triangle.

If D be the distance between the centres of the inscribed and circumscribed circles of a given spherical triangle, r, R their respective radii, prove that

$$\sin^2 D = \sin^2 (R - r) - \cos^2 R \sin^2 r. \qquad (40.)$$

26. The angular points A, B, C, D of a quadrilateral are (3, 5) (6, −2), (−1, −1), (−2, 1). Find the equations of the lines AC, BD, the tangent of the angle between them, and the area of the quadrilateral. Find also the distance between the middle points of AC and BD. (30.)

27. Define the polar of a given point with respect to a given circle, and write down its equation. Give a geometrical construction for the polar, both when the pole is inside, and when it is outside the given circle.

If PQ be the line joining any point, P, to the intersection, Q, of the polars of P with respect to two fixed circles, find the locus of the middle point of PQ. (35.)

28. Explain what is meant by the eccentric angle of a point on a given ellipse.

Write down the equations of the tangent and normal at a point whose eccentric angle is (ϕ). If CP, CD be conjugate semi-diameters of the ellipse $3x^2 + 2y^2 = 1$, find the locus of the intersection of the tangents at P and D. (35.)

29. Find the condition that the general equation of the second degree may represent—

(1) A parabola. (2) A rectangular hyperbola. (3) A pair of straight lines.

Obtain the position and magnitude of the semi-axes of the curve whose equation is—

$$13x^2 + 8xy\sqrt{3} + 21y^2 + (75 - 36\sqrt{3})x + (36 + 75\sqrt{3})y + 144 = 0. \qquad (40.)$$

30. Obtain the equations of the straight line joining the points (3, 5, 7) (2, −2, 8); also find the length and the direction-cosines of the perpendicular from the origin upon this line. (35.)

31. The angular points P, Q, R, S of a tetrahedron are (0, 1, 3), (1, 2, 4), (2, 3, 1), (3, 0, 2) respectively: find the dihedral angle between the faces P Q R and P Q S; also find the length of the perpendicular let fall from S upon the opposite face, and the volume of the tetrahedron. (40.)

32. Find the relation which must exist among the constants in order that there may be a point common to the two lines whose equations are—

$$ax + by + c = 0, \quad a'x + b'z + c' = 0,$$

and
$$\frac{x - \alpha}{A} = \frac{y - \beta}{B} = \frac{z - \gamma}{C}.$$

If the lines
$$\frac{2x - 1}{6} = y + 2 = \frac{z + 1}{2},$$

and
$$2x - 7 = y + 1 = 12 - 12z$$

intersect in P; find the equation of the plane which passes through P and is perpendicular to the line joining P to the origin. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage paper.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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41. Given the lengths of the edges of a tetrahedron, find the angle between two opposite edges.

Show that if the perpendiculars from the vertices upon the opposite faces meet at a point, pairs of opposite edges are at right angles. (50.)

42. Tangents at the extremities of an arc AB of a given circle meet at C, and a third line through C intersects the circle in D and E. Show that the arcs AB and DE cut each other harmonically.

Prove that every circle cutting an arc of another circle harmonically is orthogonal to the circle which passes orthogonally through the extremities of the arc. (50.)

43. ABC is a spherical triangle, and P any point on the sphere; great circles are drawn joining each vertex to P, and intersecting the opposite sides in D, E, F; prove that the sides of the triangle D, E, F meet the corresponding sides of the original triangle in points which lie on a great circle.

Hence show that if two diagonals of a complete spherical quadrilateral are quadrants, the third diagonal is also a quadrant. (45.)

44. Obtain, by Descriptive Geometry, the elevation of a meridian section of a hyperboloid of revolution whose axis is vertical, having given the inclination to the horizontal plane of a generator, and its shortest distance from the axis.

Draw also the traces of a plane which touches the surface at a given point. (65.)

45. What is the analytical representation of projection in geometry? Show how to project any triangle into an equilateral triangle, and any hyperbola into an equilateral hyperbola. (60.)

46. Show that the four tangents drawn to the nine-points circle of a given triangle at the points where this circle touches the inscribed and escribed circles of the triangle are also tangents to the inscribed ellipse which touches the sides of the given triangle at their middle points. (65.)

47. A conic circumscribing the triangle ABC has its tangents at the angular points respectively parallel to the opposite sides. Find the equations of the circles of curvature at A, B, C, and show that these three circles and the circumscribed circle of the triangle have a common point of intersection. (65.)

48. If a given curve of the nth degree have δ double points, and κ cusps, find the degree of the reciprocal of the given curve. Through how many fixed points in general can this reciprocal be made to pass? (60.)

49. Find the condition that the general equation of the second degree may represent (1) a paraboloid of revolution; (2) a cylinder of revolution.

Find the nature of the surface represented by—

$$x^2 + 4y^2 + 9z^2 + 12yz + 6zx + 4xy = 1.$$

(65.)

50. Show that a sphere can be drawn through any two circular sections, of opposite systems, of a given ellipsoid. If the sections are such that the radius of the sphere is constant, prove that the locus of the centre of the sphere is a hyperbola. (70.)

SUBJECT V. PURE MATHEMATICS, STAGES 6 & 7.

EXAMINER, P. T. WRIGLEY, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Sixth Stage, or from the Seventh Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Sixth Stage.—Subjects: Differential Calculus and Integral Calculus.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

---

1. Give a definition of a limit, and obtain from first principles the differential coefficient of $\log_a x$ and of $\tan x$.

   Differentiate

   (1.) $(a-x)^{3x^2}$.

   (2.) $\log \sqrt[3]{\dfrac{a^3+a^2x+ax^2+x^3}{a^2+ax+x^2}}$

   (3.) $e^{ax}\sin^{-1}\{2x\sqrt{1-x^2}\}$. (35.)

2. If $u=\{\cos^{-1}ax\}^2$ find $\dfrac{d^2u}{dx^2}$ in terms of u and $\dfrac{du}{dx}$, and obtain the equation expressing the relation between $\dfrac{d^nu}{dx^n}$ and the two next lower differential coefficients of u with respect to x. (35.)

3. Find an expression for the remainder after n terms in the expansion by Taylor's Theorem of $f(x+h)$ in a series proceeding by ascending powers of h.

Expand $\sin(2x+h)$ in powers of h, and give the remainder after four terms. (35.)

4. Show that the value of a fraction which assumes the indeterminate form, $\frac{0}{0}$, is zero, finite or infinite, as the case may be, and give a method of finding the value in any case.

$$\text{Evaluate } \frac{\log \sin 5x}{\log \sin 3x} \text{ when } x=0. \qquad (30.)$$

5. Find under what conditions $\phi(x)$ may have a maximum or a minimum value.

What is the area of the largest triangle that can be inscribed in a given ellipse, having one of its angular points at an extremity of the minor axis? (30.)

6. Obtain an expression for the radius of curvature at any point of the curve $\phi(x, y)=0$.

Show that in the rectangular hyperbola, $xy=c^2$, the radius of curvature at any point P is proportional to the cube of the distance of P from the origin. (35.)

7. Explain a method for discovering the existence of singular points on a curve whose equation is given.

Trace the curve $\frac{x-y}{y}=\frac{x^2}{c^2}$, carefully noting any singularities. (40.)

8. Find the value of the following indefinite integrals:—

$$\int\frac{(x-1)}{\sqrt{x^2-x+3}}\,dx,\ \int\frac{\left(1+2x^{\frac{3}{4}}\right)^{\frac{2}{3}}}{x^3}\,dx,\ \int\frac{dx}{1-\tan^2 x}. \qquad (35.)$$

9. Show that $f(b)-f(a)=\Sigma f'(x)dx$, where $\Sigma f'(x)dx$ denotes the sum of an infinite number of terms of the type $f'(x)dx$ obtained by successively increasing x by infinitesimal increments dx from a to b. Find the values of—

$$\int_0^{\frac{\pi}{2}}\sin^6 x\,dx,\ \int_a^\beta\frac{dx}{\cos x\,(3-\cos x)},\ \int_a^c\frac{dx}{\sqrt{1-e^{2x}}} \qquad (40.)$$

10. Find the area enclosed between the parabola, $y^2=4ax$, and its evolute, $27ay^2=4(x-2a)^3$; also find the length of the perimeter of this area. (40.)

11. Let O be the pole of the cardioid, whose equation is $r=a(1+\cos\theta)$, and OP, OQ lines trisecting the area of the cardioid. If the angle POQ be denoted by 2ϕ, show that

$$\sin\phi(4+\cos\phi)+3\phi=\pi. \qquad (40.)$$

12. Show that the surface generated by the revolution of a cycloid round the tangent at the vertex is half that generated by the revolution of the cycloid round its base. (35.)

Seventh Stage.—Subjects: Differential Calculus, Integral Calculus, Differential Equations, and Finite Differences.

INSTRUCTIONS.

Read the General Instructions at the head of the Sixth Stage paper.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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21. If $z=x+y\phi(z)$ obtain a series for $F(z)$, proceeding by ascending powers of y.

Given

$$z=\tfrac{1}{2}+\frac{z^6}{4},$$

find a value of z correct to four places of decimals. (40.)

22. Investigate the conditions for a maximum or a minimum value of a function of two independent variables.

The volume of a cone being given, find the altitude, so that the whole surface of the cone may be a minimum. (40.)

23. Define contact of the n^{th} order between two curves. Find the locus of the centres of rectangular hyperbolas which have contact of the second order with a given curve at a given point on it. (45.)

24. State the restrictions under which it is permissible to differentiate within the sign of integration.

Evaluate the definite integrals

$$\int_0^{\frac{\pi}{2}}\frac{dx}{a^2\sin^2x+b^2\cos^2x},\ \int_0^{\frac{\pi}{2}}\frac{\sin^2x\,dx}{(a^2\sin^2x+b^2\cos^2x)^2},\ \int_0^{\frac{\pi}{2}}\frac{dx}{(a^2\sin^2x+b^2\cos^2x)^2}$$

(50.)

25. Find the area of that portion of the surface

$$z^2+(x\cos\alpha+y\sin\alpha)^2=c^2$$

which is comprised in the positive octant of the co-ordinate axes. (50.)

26. Obtain the value of

$$\iint \frac{1+\frac{c^2-a^2}{a^4}x^2+\frac{c^2-b^2}{b^4}y^2}{\sqrt{1-\frac{x^2}{a^2}-\frac{y^2}{b^2}}}\,dx\,dy$$

where the integration extends to all points within the ellipse $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ (50.)

27. Obtain the general solution of the linear differential equation

$$\frac{dy}{dx}+Py=Q.$$

Integrate the equations

$$\frac{dy}{dx}=y\tan x+x^2\sin x,$$

$$\frac{dy}{dx}=y(xy^2-1),$$

$$x\frac{dy}{dx}+y=y^2\log x.$$

(50.)

28. Find the differential equation to a curve such that the segment intercepted on the axis of x by the tangent and normal at any point may be of constant length. Integrate the equation, and trace the curve. (55.)

29. Integrate the equation

$$x^3\frac{d^2y}{dx^2}=\left(x\frac{dy}{dx}-y\right)^2;$$

also the simultaneous equations

$$\left.\begin{aligned}3\frac{dy}{dx}+7\frac{dz}{dx}+y+24z&=3\\4\frac{dy}{dx}+9\frac{dz}{dx}+2y+31z&=e^x\end{aligned}\right\}$$

(55.)

30. Explain what is meant by the successive differences of a function of x. Find the values of

$$\Delta^2\frac{a^{2x}+a^{4x}}{(a^2-1)^2},\ \Delta^n x^{m+n},\ \Delta^n\frac{1}{x},$$

and $\Delta^n\sin ax\cos bx$. (40.)

31. Define successive values of a function of x. Express $\Delta^n u_x$ in terms of u_x and its successive values, and deduce a series for $\Delta^n 0^m$. Establish the following formulæ:—

$$\Delta^n 0^{n+1}=\frac{n(n+1)}{2}\Delta^n 0^n$$

$$\Delta^n 1^{m+1}=(n+1)\Delta^n 1^m+n\Delta^{n-1}1^m.$$

(45.)

32. Sum to n terms

(1) $\frac{1}{1.5.9}+\frac{3}{5.9.13}+\frac{5}{9.13.17}+\ldots.$

(2) $1.3.5\sin\theta+3.5.7\sin 2\theta+5.7.9\sin 3\theta+\ldots$ (45.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions, and may select them from any part of the paper.

The values attached to the questions differ but little from one another.

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41. Transform the expression $\frac{d^2V}{dx^2}+\frac{d^2V}{dy^2}+\frac{d^2V}{dz^2}$ into one in which r, θ, ϕ, are the independent variables, where $x=r\sin\theta\cos\phi$, $y=r\sin\theta\sin\phi$, $z=r\cos\theta$.

42. If a chord of given length move inside any closed curve, and a point P, which divides the chord into segments, a and b, trace out another closed curve, show that the area comprised between the two curves is equal to that of an ellipse whose semi-axes are equal to the segments of the chord.

43. Find the values of the definite integrals,

$$\int_0^\pi \frac{\cos mx\,dx}{1-2a\cos x+a^2},\quad \int_0^\infty \frac{(\tan x)\,dx}{x},\quad \int_0^\infty \frac{\sin x\,dx}{\sqrt{x}}.$$

44. Give Gauss's definition of the integral curvature of a portion of a curved surface bounded by a closed curve. Deduce the measure of curvature at a point of the surface; express it in terms of the principal radii of curvature at the point; and show that it is unaltered if the surface be deformed.

45. In the functional equation $\phi(x, y, z, a)=0$, where a is a variable parameter, find the condition which must be satisfied if two surfaces of the family cut each other at right angles.

Given the ellipsoid $\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$, find the equations of the other confocal conicoids which form with it a mutually orthogonal system.

Show also that the position of any point in space may be defined in terms of the parameters of such a system of surfaces.

46. Apply the Calculus of Variations to determine the nature of the curved line joining two given points, such that the surface generated by its revolution about a fixed axis, in the plane of the given points, may be of minimum area.

47. Obtain the differential equation of the class of curves such that the radius of curvature is equal to $\frac{c}{\sin^n\phi}$, where ϕ is the angle between the tangent and the radius vector, and find what particular curve results when $n=3$.

48. Obtain a solution of the differential equation

$$x^2\frac{d^2y}{dx^2}+x\frac{dy}{dx}+(x^2-a^2)\,y=0$$

in the form of a series, and also in the form of a definite integral.

49. Give a general method for obtaining a complete integral of the partial differential equation of the first order

$$F(x, y, z, p, q)=0.$$

Solve the equation $p(1+q^2)=q(z-a)$.

50. Integrate the equations of differences

(1.) $u_{x+2}-6u_{x+1}+8u_x=x^2+3^x$.

(2.) $u_{x+1}u_x+au_{x+1}+bu_x+c=0$.

SUBJECT VI. THEORETICAL MECHANICS.

Examiner, REV. J. F. TWISDEN, M.A.

General Instructions.

If the rules are not attended to, your papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to *attempt* more than SEVEN QUESTIONS. You may select them from any part of the paper.

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1. State any one property of the centre of gravity of a body.
   A particle is placed at an angular point of a triangular lamina of uniform density; the weights of the particle and lamina are equal; show in a diagram where the centre of gravity of the whole is situated. (10.)

2. A and B are two rigidly connected points 5ft. apart; forces of 5 and 7 units act at A and B respectively at right angles to AB, and in the same direction; they are balanced by a force P acting at a point O in AB; find, (*a*) the magnitude of P, (*b*) the distance AO, and (*c*) show in a diagram the direction in which P acts. (12.)

3. A rod (AB) can turn freely round a hinge at A; it rests in an inclined position against a smooth fixed point near the end B; show in a diagram the forces which keep the rod at rest, and name them. (16.)

4. ABC is a triangle having a right angle at C; BC is 12 ft., and AC is 20 ft.; P is a point in the hypotenuse AB such that AP is one-fourth of AB; a force of 50 lbs. acts from C to B, and one of 100 lbs. from C to A. (*a*) Find the moments of the forces with respect to P; (*b*) find the sum (*i.e.*, the algebraical sum) of the two moments; (*c*) if the point P were fixed, in what direction would the forces make the triangle revolve? (14.)

5. ABCD is a thin rectangular plate weighing 50 lbs., AB is 10 ft., BC is 2 ft.; the plate is suspended by the middle point of its upper edge AB, and then, of course, AB is horizontal. If a weight of 5 lbs. is now placed at A, AB will become inclined to the horizon; show how to find the angle of inclination, either by calculation or construction. (16.)

6. What is the horse-power of the engine which draws a train with a uniform rate of 45 miles an hour, against a resistance of 900 lbs.? (10.)

7. A body, whose velocity undergoes constant acceleration, has at a certain instant a velocity of 22 ft. a second, in the following minute it describes 10,320 ft.; find the constant acceleration. (10.)

8. The velocity of a body is increased uniformly in each second by 20 ft. a second; by how many yards a minute will its velocity be increased in one minute? (12.)

9. A body is constrained to move in a circle by means of a string fastened to the centre; the radius of the circle is 3 ft., the mass of the body 12 lbs., and the velocity 40 ft. a second; find the tension of the string (*a*) in poundals, (*b*) in pounds. ($g = 32.$) (14.)

10. When a body is wholly or partly immersed in water, what is the magnitude of the resultant fluid pressure on it; in what direction and along what line does the resultant act?

A body, whose volume is 5 cubic feet, and specific gravity 1·2, hangs by a string suspended in water, which completely covers it; what force exerted along the string is needed to support the body? (12.)

11. Describe Nicholson's Hydrometer, and how it is used for finding the weight of a small body.

The standard weight being 1,200 grains, a body is placed in the upper pan, and it is found that 200 grains must be added to sink the hydrometer to the standard point. The body is now placed in the lower pan, and it is found that 450 grains must be placed in the upper pan to sink the instrument to the standard point. What is the specific gravity of the body? (14.)

12. Explain the advantage gained in Hawksbee's air pump by the use of two pistons.

If the capacity of the receiver of an air pump is six times that of the barrel, and the pressure of the air in the receiver before the first stroke equal to the pressure of 29·4 inches of mercury, what will be the pressure after the first stroke? (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.

You are not permitted to *attempt* more than *eight* questions. You may select them from any part of the paper.

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21. Assuming that the "parallelogram of forces" is true for the direction, show that it is true for the magnitude of the resultant.

Find the cosine of the angle between the directions of forces of 5 and 7 units, which have a resultant of 8 units. Show that the angle itself exceeds 90°. (20.)

22. When a force and a couple act in the same plane on a rigid body, find their resultant.

Draw a square ABCD and its diagonal AC; two forces of 10 units act from A to B and from C to D respectively, forming a couple, a third force of 15 units acts from C to A; find their resultant, and show in a diagram exactly how it acts. (20.)

23. A rod is supported horizontally on two points A and B, 12 ft. apart; between A and B points C and D are taken, such that AC = BD = 3 ft.; a weight of 120 lbs. is hung at C, and a weight of 240 lbs. at D; the weight of the rod is neglected; take a point O midway between A and B, and find with respect to O the algebraical sum of the moments of the forces acting on the rod on one side of O. (20.)

24. A lamina of uniform density has the form of a quadrilateral with two sides parallel; find the position of its centre of gravity, having given the lengths of the parallel sides, and the length of the line joining their middle points. (20.)

25. A hemispherical bowl is held firmly with its middle radius vertical; a uniform rod AB is fastened by a hinge to the lowest point A of the bowl, and is so long that its middle point rests upon the edge of the bowl; show that the reaction of the hinge is exerted in the direction A to B, and find that reaction, and the reaction of the edge of the bowl in terms of the weight of the rod. If a weight were placed at B, how would it affect the direction of the reaction of the hinge? (30.)

26. Find, without using the principle of work, the relation between the power and the weight in the screw press, taking into account the friction between the threads of the screw and the companion screw. (20.)

27. A shaft 560 ft. deep, and 5 ft. in diameter is full of water; how many foot-pounds of work are required to empty it, and how long would it take an engine of $3\frac{1}{2}$ horse power to do the work? N.B.—Of course, it is to be assumed that there is no flow of water into the shaft. You may take $\pi = 3\frac{1}{7}$. (20.)

28. Find the ratio of the height to the length of a smooth inclined plane, down which when a particle slides the acceleration of its velocity is one-fifth of the acceleration of the velocity of a body falling freely under the action of gravity.

If such a particle has a mass of 12 lbs., find its velocity and its kinetic energy acquired in descending along 100 ft. of the length of the plane. ($g = 32$.) (25.)

29. A particle describes a circle with a constant velocity, show that the force acting upon it is always directed to the centre, and find the magnitude of the force in terms of the radius of the circle, and the mass and velocity of the particle. (25.)

30. Define the moment of inertia of a system of particles. Find the moment of inertia of a rod of uniform density, with reference to an axis passing through one end at right angles to its length.

A rod 6 ft. long, weighing 12 lbs., revolves uniformly 30 times a minute about an axis at right angles to its length and passing through one end; find its kinetic energy. (30.)

31. If two liquids do not mix, show that their common surface is a horizontal plane.

A conical vessel with its base horizontal is filled partly with mercury and partly with water; internally the radius of the base is 6 in., and the height 18 in.; the volume of the mercury is seven times that of the water; find the pressure on the base, having given that a cubic inch of water weighs 250 grains, and a cubic inch of mercury 3,400 grains. (30.)

32. A cubic inch of air under a pressure of 15 lbs. per square inch is mixed with two cubic inches of air under a pressure of 45 lbs. per square inch; if the mixture occupies $3\frac{1}{3}$ cubic inches, what is the pressure of the mixture? (Temperature the same in all cases). (20.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.

You are not permitted to *attempt* more than *eight* questions. You may select them from any part of the paper.

41. Find the position of the centre of gravity of a segment of a sphere.

Verify your result by deducing from it the position of the centre of gravity of a sphere. (40.)

42. Show that any system of forces acting on a rigid body can be reduced to a single force acting at any arbitrarily chosen point and a couple.

ABCD is a face of a cube, AE, BF, CG, DH are parallel edges; equal forces (P) act from D to A, G to C, and E to F respectively; show how to reduce the three forces to two. (40.)

43. ABC is a hole, having the shape of an equilateral triangle, cut in a horizontal table; a sphere of uniform density stands in the hole (which is not large enough to let the sphere through). Given the weight and radius of the sphere, and the length of a side of the triangle, find the pressure on each side of the triangle.

Also solve the problem on the supposition that no two sides of the triangle are equal. (60.)

44. A uniform beam is supported on many points, all in the same horizontal line, so that the only forces acting are the weight of the beam, and the reactions of the fixed points. Let A and B be any two consecutive fixed points, B to the right of A; show that the sum of the moments with respect to A of the forces to the right of A is—

$$M + Q.AB - \tfrac{1}{2}w.AB^2$$

where M denotes the sum of the moments with respect to B of the forces to the right of B, Q the sum of the forces at and to the right of B, and w the weight of unit length of the beam; the reactions and their moments being reckoned positive. (40.)

45. There are two rectangular beams of the same length, and of the same material; each is supported horizontally on two points, one under each end; if the curvature at the middle point of the one is double the curvature at the middle point of the other, show that the depth of the first is to the depth of the second as 1 to $\sqrt{2}$. (40.)

46. Define the work of a force, whose point of application is moved in a given direction through a small distance.

Let AB and CD be two diameters of a circle at right angles to each other. A particle M is constrained to move along the circumference from A through C to B, and is acted on by a constant force (P) in the direction M to B; show that the work done by P is P.AB, and that the work done by P while M moves from A to C, is to that which it does while M moves from C to B as 5 to 12 very nearly. (50.)

47. When a plane lamina is moved from one position to another in its own plane, show that the transfer can be effected by a rotation round a fixed axis at right angles to the plane. Point out an exceptional case, if there be one. (40.)

48. What is meant by the expression $\Sigma(mxy)$ which occurs in treatises of rigid Dynamics?

Calculate its value in the following case:—AOB is a triangular lamina of uniform density, having a right angle at O, OB is taken as the axis of x, and OA as that of y. (50.)

49. AB is a diameter of a circular plate of uniform density, which can turn freely round a fixed horizontal axis through A, at right angles to its plane. A particle whose mass is half that of the plate is fastened to B. The plate is placed with B vertically over A, and is then allowed to fall; find, at the instant that B is vertically below A, the body's kinetic energy, and its angular velocity. (50.)

50. A hard homogeneous cylinder rolls, without any slipping, down a rough inclined plane; determine the acceleration of its velocity down the plane, and the amount of friction called into play. (60.)

51. Describe briefly the common hydrometer, and investigate a formula for comparing the specific gravities of fluids by means of it.

A common hydrometer floating in a liquid whose specific gravity is 1·1, has 5 in. of the stem above the surface; when it floats in a liquid whose specific gravity is 1·2 it has 6 in. of the stem above the surface; how much of the stem will be above the surface when it floats in a liquid whose specific gravity is 1·3? (40.)

52. Assuming the usual formula for the distance of the metacentre (M) from the centre of gravity (H) of the displaced water, viz., $V.HM = k^2A$; find the position of the metacentre of a cone floating with its vertex downward, in terms of its dimensions and specific gravity.

If the specific gravity of a cone is 0·729, show that the position will be stable if the tangent of half the vertical angle of the cone exceeds $\frac{1}{3}$. (50.)

SUBJECT VII. APPLIED MECHANICS.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You may not *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

1. What are the conditions to be satisfied by a standard surface plate? What material is selected for such a plate, and for what reason? Why is it necessary to have *three* surfaces under operation in order to prepare an original true surface? (15)

2. Explain the method of estimating the work done by a force, and define the unit of work.

   The surface of the water in a well is at a depth of 20 ft., and when 500 gallons have been pumped out, the surface is lowered to 26 ft. Find the number of units of work done in the operation, the weight of a gallon of water being 10 lbs. (15)

3. A uniform bar 4 ft. long and weighing 4 lbs., can turn about a fulcrum at one end, and a weight of 10 lbs. is hung upon the bar at a distance of 1 foot from the fulcrum. Find the upward force at the free end which will keep the bar horizontal. (10)

4. A toothed wheel runs in gear with two parallel racks, one above and the other below it, the wheel being free to run between the racks. If the upper rack has a velocity of 2 ft. per second in one direction, and the lower rack a velocity of 3 ft. per second in the opposite direction, what is the velocity of the centre of the wheel? (20)

5. What is a cam? Show, with a sketch, how to obtain by means of a cam a motion in a direction parallel to the axis of rotation. (15)

6. A cubical box or tank with a closed lid, the length of a side of which is 4 ft., rests with its base horizontal, and an open vertical pipe enters one of its sides by an elbow. The tank is full of water, and the pipe contains water to the height of 1 foot above the top of the tank. What are the pressures of water on the top, bottom, and sides of the tank? (Given, the weight of a cubic foot of water = 62½ lbs.) (20)

7. Explain, with a sketch, the manner in which the principle of work is applied in determining the relation of P to W in the case of the endless screw and worm-wheel.

   The lever handle which works the screw being 14 inches long, the number of teeth in the worm-wheel 20, and the load being a weight of 1,000 lbs. hanging upon a drum of 12 inches diameter on the worm-wheel shaft, find the force to be applied at the end of the lever handle in order to support the weight. (20)

8. Describe the hydraulic accumulator for storing up water under pressure. If the ram of the accumulator be 6 inches in diameter, what load will be required to produce a water pressure of 500 lbs. on the square inch? To what head of water would this pressure correspond? (20)

9. Describe, with a sketch, the Geneva stop, and explain its action. (15)

10. What is steel? How may a piece of steel be hardened and tempered? Describe, as an example, the process of making a chisel for chipping cast iron. (15)

11. A beam of timber, rectangular in transverse section, is 2 inches broad, 3 inches deep, and 4 feet in length, and rests upon supports at its ends. The breaking load on the centre is 2,000 lbs. What would have been the breaking weight if the beam had been 4 inches deep, 2 inches broad, and 4 feet between the supports, but loaded at a distance of 1 foot from the end? (15)

12. Explain the use of an air vessel in connection with a force pump. Sketch a section through a double-acting force pump, showing the valves and the connection of the pump with the air vessel, and explain the action of the pump. (20)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

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21. A railway train, exclusive of engine, weighs 150 tons, and in starting along a level line from rest it attains a speed of 30 miles an hour in 5 minutes. What has been the mean pull between the engine and train, the resistances being taken at 10 lbs. per ton? (30)

22. What must be the difference in the diameters of a compound wheel and axle so that the velocity of P may be 100 times that of W, the length of the handle being $2\frac{1}{2}$ feet? (35)

23. In stone breaking machines it is common to use a "toggle joint." Explain the principle on which its action depends, and show by a diagram the mode of applying it to such machines. (35)

24. Describe the siphon and explain its action. In a siphon on a large scale, employed for drainage, a stand pipe, communicating with an air pump, is attached to the top of the siphon tube, also the stand pipe is fitted with one or more taps for the admission of air. For what purposes are the air pump and the air taps respectively required? (35)

25. Explain the use of change wheels in a screw-cutting lathe. It is desired to cut a screw of $\frac{5}{8}$-inch pitch in a lathe with a leading screw of 4 threads to the inch, using 4 wheels. If both screws be right-handed, what wheels would you employ? (35)

26. A beam will safely carry a stationary load of 5 tons with a deflection of 2 inches, from what height may a weight of 200 lbs. be let drop upon the same beam without deflecting it to a greater extent? 40)

27. Describe the construction and action of mechanism for obtaining the "feed" in a drilling machine, showing the manner in which the rotation of the drill spindle and its advance take place simultaneously. (40)

28. Show, by a sketch, the combination of wheel work necessary for an eight-day clock, and give numbers to the wheels which would produce the motion required, pointing out the axis or arbor to which the minute hand is attached. How is the motion of the hour hand obtained? (40)

29. Sketch and describe some form of dynamometer, and explain how it is applied for ascertaining the power given out by a prime mover.

The power of a portable engine is tested by passing a strap or belt over the fly wheel, which is 5 feet in diameter; one end of the belt is secured to a spring balance, and a weight of 300 lbs. hangs on the other end. What is the horse power of the engine when the balance registers a tension of 180 lbs., and the fly wheel makes 150 revolutions per minute? (40)

30. Draw the bending moment and shearing stress diagrams for a beam 12 feet long, supported at both ends, and loaded with weights of 4 and 6 tons at distances of 3 and 8 feet respectively from one end of the beam. Explain fully the mode of arriving at these diagrams. (40)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not *attempt more than six* questions.

The value attached to each question is shown in brackets after the question.

41. What do you understand by energy, and how is it measured? The head of a steam hammer weighs 50 cwt., steam is admitted on the under side for lifting only, and there is a drop of 5 feet. What will be the average compressive force exerted during a blow from this hammer, on the supposition that the duration of the blow, that is, the time during which the hammer is compressing the iron under operation, is $\frac{1}{80}$ second? (50)

42. In a keyless watch describe, with sketches, the mechanism for winding the spring and for setting the hands. How is the reverse motion of the winding piece rendered inoperative? (70)

43. Describe that modification of Watt's governor for steam engines where a load is carried on the central spindle. If the load be 36 lbs., and each ball weighs 4 lbs., the arms and connecting links being of equal length, find the height of the cone for 180 revolutions per minute. If the speed be suddenly increased to 185 revolutions per minute, what lifting effort would the governor exert? (60)

44. Investigate an expression for the moment of resistance to torsion of a given cylindrical shaft when subjected to a given twisting moment.

What is the maximum horse-power which could be transmitted by a shaft 3 inches in diameter when making 150 revolutions per minute, it being given that the shearing stress in the material is not to exceed 7,500 lbs. per square inch? (70)

45. Sketch and describe the mechanism for feed motions:—(1) In a machine where there is a reciprocating movement, as in a planing machine; (2) Where there is a continuous movement, as in a machine for boring cylinders. (60)

6. A triangular jointed frame is subjected to the action of three balancing forces applied at its angular points, explain the method of setting out a stress diagram of the forces acting at each joint.

Taking the case of a Warren girder, supported at the ends, where the bracing bars are each inclined at 60° to the horizon, there being 4 bays in the lower boom and 3 bays in the upper boom, find the stresses in the several parts when there are two loads of 1,000 lbs. on the lower boom, one in the centre, and the other half way between the centre and one end. (70)

47. Show a method of obtaining a comparison between the angular velocities of two axes inclined at a given angle and connected by a Hooke's joint. By what arrangement of a double joint can the above inequality be got over? Explain the action in the altered form of construction. (70)

SUBJECT VIII. SOUND, LIGHT, AND HEAT.

EXAMINERS, PROFESSOR W. GRYLLS ADAMS, M.A., F.R.S., AND
PROFESSOR A. W. REINOLD, M.A., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary or the Advanced or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions. Of these **not more than *four* may be selected from the same section.**

The value attached to each question is the same.

SECTION I.

1. State Boyle's law, and explain under what conditions it is true.

   What will be the change in volume of a quantity of air which measures 20 cubic feet, if the pressure on it changes from 15 lbs. on the square inch to 10 lbs. on the square inch?

2. What is meant by a *wave of sound* and by the *length of a wave?* Explain how sound is transmitted through air.

3. Describe the way in which the velocity of sound in water has been determined.

4. A steel wire, one yard long and stretched by a weight of 5 lbs., vibrates 100 times per second when plucked. If I wish to make two yards of the same wire vibrate *twice* as fast, with what weight must I stretch it?

5. Describe a mouth (or flue) organ pipe. If two such pipes of the same length are sounded, one of them being open and the other closed, how do the notes differ from each other?

SECTION II.

6. Explain, by the aid of a sketch, how shadows are produced. Hence explain an eclipse of the Sun.

7. Describe the method of using a Bunsen photometer to compare the illuminating powers of two sources of light.

8. Explain how the appearance of a stick partially immersed obliquely in water agrees with the law of refraction.

9. What do you understand by the focal length of a convex lens?

   If a small object be placed so that its distance from the lens is a little greater than the focal length, where will the image be? Will it be upright or inverted, real or virtual?

10. A right angled isosceles prism is sometimes used as a plane mirror. Explain, by the aid of a sketch, how it can be so used.

SECTION III.

11. How would you prove that zinc expands more than copper when rods of the two metals are heated through the same range of temperature?

12. Water is said to have its maximum density at 4° C. Explain what this means.

    In what respect is the behaviour of mercury different from that of water when both are gradually warmed from 0° C.?

13. Explain, by the aid of a sketch, how a building is heated by hot water carried in pipes from a boiler in the basement of the building.

14. Define dew-point. How is dew formed, and why is it more copious on some substances than on others?

15. State the effect on the volume of a given mass of air, of altering its temperature without altering its pressure; also the effect on its pressure of altering its temperature without altering its volume.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions. Of these not more than *four* may be selected from the same section.

The value attached to each question is the same.

SECTION I.

21. How would you compare the velocities of sound in different gases?

22. Describe the method of testing the state of disturbance of the air at any part of an open organ pipe when a musical note is being produced from it.

    What results will be obtained when the first harmonic is being produced from the pipe?

23. Four strings of the same material and length, but of thicknesses 1, 1·5, 2·5, and 3, are stretched on a violin and tuned so as to give successive fifths. Compare the tensions of the several strings. (The thinnest string is to give the highest note.)

24. Explain how to determine the time of vibration of a given tuning fork, and state what apparatus you would require for the purpose.

25. Describe an experiment to prove that two sounds may produce perfect silence.

SECTION II.

26. Explain how to determine the focal length of a double convex lens without the aid of sun light.

27. Explain how to measure the refracting angle of a prism, and the refractive index of the material of the prism.

28. Describe the method adopted by Fizeau for determining the velocity of light.

29. A brightly illuminated vertical slit in the shutter of a dark room is looked at through a prism with a vertical edge. Draw a picture showing how the image seen is formed, and explain why it is coloured.

30. A convergent pencil of light falls upon a concave lens. Trace the position of the image as the point of convergence of the pencil moves from an infinite distance up to the lens.

SECTION III.

31. Define specific heat.

A copper calorimeter having a mass of 125 grammes contains 400 grammes of water at 15° C.; into this are placed 556 grammes of copper at a temperature of 95° C., and the final temperature is 24° C., find the specific heat of copper.

32. What is meant by saying that the mechanical equivalent of heat is 772 foot pounds? If the standard substance were iron (whose specific heat is 0·114), what would be the value of the mechanical equivalent of heat?

33. Distinguish between the apparent and the absolute expansion of mercury. Describe some method by which one *or* the other may be experimentally determined.

34. Describe the method of using a dew-point hygrometer to determine the hygrometric state of the air in a room.

35. State the laws of fusion. What is the effect of pressure in changing the temperature at which water freezes?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are expected to attempt all the questions.

The value attached to each question is the same.

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41. Explain how to determine the focal length, the curvatures, and the index of refraction of a double convex lens by means of the optical images obtained by reflection or by refraction at its surfaces.

42. Explain the construction of a Nicol's prism.
    A ray of light passes through a crystal of Iceland spar, then through a selenite plate, and finally through a Nicol's prism. Explain the changes which it undergoes in its passage through each.

43. Describe Andrews' researches on carbonic acid at various temperatures and pressures. Draw the isothermal lines for this substance, and explain the terms *critical temperature* and *critical pressure*.

44. Give an account of Dulong and Petit's investigations on the laws of cooling of a hot body in vacuo.

45. Distinguish between the isothermal and the adiabatic elasticity of a gas, and show their relation to each other. Hence explain how the velocity of sound in the gas may be calculated. In the case of atmospheric air, point out what data are necessary for the calculation.

Practical Examination.

Sound.

Determine by using a wire stretched with a weight the absolute pitch of a tuning fork.

Light.

1. Find the wave length of a given coloured light—
   (*a*) By means of Newton's rings, using sodium light as a standard, or (β) by diffraction grating and spectrometer.

2. Determine the values of the refractive index and the curvatures of the faces of a given lens.
3. Determine the rotating power of a given liquid.

Heat.

1. Determine the specific heat of a solid, and, using this result, find the latent heat of water.
2. Determine the specific heat of the given liquid.

SUBJECT IX. MAGNETISM AND ELECTRICITY.

EXAMINERS, PROFESSOR G. CAREY FOSTER, F.R.S.,
AND PROFESSOR A. W. RÜCKER, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than *eight* questions.

You may select only *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

1. A small magnet is placed upon a flat cork which floats in a basin of water, and it is fastened to the cork with a little wax. Describe and explain the behaviour of the magnet (1) when under the influence of the earth's magnetism alone, (2) when an artificial steel magnet is brought near to it.

2. A compass needle and a straight strip of soft iron of the same length as the compass needle are fastened together so as to be in contact with each other at both ends. Will the force which tends to make the combination point north and south be the same as that which would act on the compass needle alone? Give reasons for your answer.

3. How would you construct an astatic needle out of a uniformly magnetized strip of watch spring, which you are allowed to bend or break as you please?

4. If a compass were carried round the equator, would it point in the same direction at all places? If not state, as nearly as you can, what changes would be observed in its behaviour during the journey.

Frictional Electricity.

5. A pith ball is suspended from a metal stand by a fine thread. If you have a strongly electrified glass rod, how can you find out whether the thread is a conductor or a non-conductor of electricity?

6. If you were given a negatively electrified stick of sealing wax and two metal balls mounted on insulating supports, how would you, with this apparatus, charge the balls with opposite kinds of electricity? How could you afterwards find out whether you had charged the balls as you intended, and whether their charges were equal or unequal?

7. An insulated conductor, A, is brought near to the cap of a gold leaf electroscope which has been charged positively. State and explain what will happen (1) if A is unelectrified; (2) if it is charged positively; (3) if it is charged negatively.

8. Describe any experiment by which you could prove that when electrification of one kind is produced, the opposite kind is also produced in equal quantity.

9. An orange, into which a sewing needle has been stuck, point outwards, is suspended by a dry silk thread. A charged body is brought near to it, 1st, opposite the point of the needle; 2nd, opposite the side remote from the needle. State and explain the electrical effect in each case.

Voltaic Electricity.

10. Describe and explain any workable experiment to prove that the terminals of a galvanic battery differ electrically in the same way as the conductors and rubber of an electrical machine at work, but to a less extent.

11. The platinum and copper plates of a Grove's and a Daniell's cell are connected by a wire. Would there be a current if the zinc plates were also connected, and if so in which direction would it flow?

    What reason have you for your answer?

12. The current from a voltaic battery is passed at the same time through a thin wire and through dilute sulphuric acid, connected in series. What will happen to the wire and to the dilute acid; and what change (if any) will be produced in each case by reversing the battery connections, so as to alter the direction of the current through the wire and liquid?

13. Two compass needles are arranged near each other so that both point along the same straight line. A wire connecting the platinum and zinc ends of a battery is stretched vertically half way between the needles. How will the current in the wire affect the needles, and how will the result depend upon whether the platinum terminal is connected with the upper or lower end of the wire respectively?

14. If you were given any galvanic cell you chose, wire with an insulating covering, and a bar of soft iron, one end of which was marked, state exactly what arrangements you would make in order to magnetize the iron so that the marked end might be a north-seeking pole? Give a diagram.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *eight* questions.

You may only select *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

21. What effect (if any) is produced (1) on the weight, (2) on the position of the centre of gravity, of a piece of steel by magnetizing it? Give reasons for your answer.

22. Two long magnets are placed vertically with their north poles (A and B) at the same level as the north pole (C) of a compass needle, one being magnetic east and the other

magnetic west of C. If the compass is not deflected when the distance AC is twice BC, and if all the magnets are so long that the effects of their south poles may be neglected, show what are the relative strengths of the poles A and B.

23. A compass needle is suspended at the centre of a circle drawn on a horizontal table. A magnet is moved round the compass so that its centre always lies on this circle, and that its length always points magnetic east and west. How and why will the position of the compass needle change as the magnet is carried round it?

24. Two magnets A and B are in turn suspended horizontally by a vertical wire so as to hang in the magnetic meridian. To deflect the magnet A through 45° the upper end of the wire has to be turned once round. To deflect B through the same angle it has to be turned round one and a half times. Compare the moments of the two magnets.

Frictional Electricity.

25. Describe and explain the construction and action of the essential parts of Sir W. Thomson's quadrant electrometer.

26. Two insulated metallic plates are placed facing each other, and each of them is connected with a separate gold leaf electroscope. If one plate is charged, the leaves of both electroscopes diverge. If now an unelectrified slab of sulphur is introduced between the plates without touching either, state and explain the effect on each electroscope.

27. A metal ball A is placed at a distance of 1 foot from an electrified ball B. It is then connected for a moment with the earth. If the ball A is now placed 2 feet from B, and again connected with the earth, compare the charges acquired by A in the two cases and explain the results, assuming that, in each case, the charges of both A and B are uniformly distributed over them.

28. An electrical machine is placed in an insulated chamber which is lined inside with tinfoil. The rubber of the machine is connected with the tinfoil. What will be the effect upon an electroscope placed outside and connected with the chamber when the machine is in action? Explain your answer.

29. How would you arrange an experiment to deflect the needle of a galvanometer by a current produced by a frictional electrical machine? Would it be necessary, in such an experiment, to insulate the wires connecting the galvanometer with the electrical machine more carefully than if a galvanic cell were used in place of the machine Give reasons for your answer.

Voltaic Electricity.

30. When a coil of wire is connected in circuit with a battery and a tangent-galvanometer, the galvanometer shows a deflection of 45°. If the wire is replaced by resistances of 24 and 25 ohms in turn, the deflection is 46° in the first case and 44° in the second. Find the resistance of the wire. Tan 44°=0·966; tan 45°=1·000; tan 46°=1·036.

31. A current is passed through a coil of wire and through a voltameter arranged in series with it. If the strength of the current is altered so that the heat produced per minute in the coil of wire is doubled, show what change will be produced in the rate at which chemical action takes place in the voltameter.

32. If an increase of the resistance of a circuit by 10 ohms causes the strength of the current to decrease from 5 to 2, find the total resistance of the circuit after the change.

33. Two bars of bismuth A and B are attached to the extremities of a bar of antimony, and a current is passed from A to B. Is there any difference, and if so what, between the effects produced at the two junctions? How does the effect in each case depend on the strength of the current?

34. A piece of wire is bent into the form of a rectangle, and the ends are joined. It is laid upon a horizontal table with two sides pointing magnetic north and south. If the rectangle be turned about the east side as a hinge so as to lie on the table to the east instead of to the west of it, what will be the direction of the current which circulates in the wire during its motion, in consequence of the earth's magnetism?

Honours Examination.

Full marks can only be got by answering all the questions.

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41. Describe the apparatus and operations necessary for the determination of the mechanical equivalent of heat, by means of observations on the heat developed in a wire when an electric current is passed through it.

42. How would you determine the value of an unknown resistance if you were supplied with a battery, a Thomson's

quadrant electrometer, and any wires, keys, or resistance boxes you might require? If the electrometer were not fitted with a replenisher and gauge, how would you guard against errors due to a loss of charge by the electrometer during the experiment?

43. Explain exactly how you would determine experimentally in absolute measure the electromotive force of a constant cell.

44. Two metal balls, supported by insulating stems at a small fixed distance apart, are electrified so as to attract each other with force *f*. If now the balls are immersed in bisulphide of carbon (specific inductive capacity = 2), show what force they will exert on each other:—

(1.) If their respective charges remain the same as when they were surrounded by air.

(2.) If the difference of their potentials is the same as when they were in air.

45. In an experiment for the determination of the capacity of a condenser by the ballistic-galvanometer method, connexions were made as follows: The current from a battery of Leclanché cells was allowed to pass continuously through a set of coils of total resistance 11,000 ohms. Then (fig. 1)

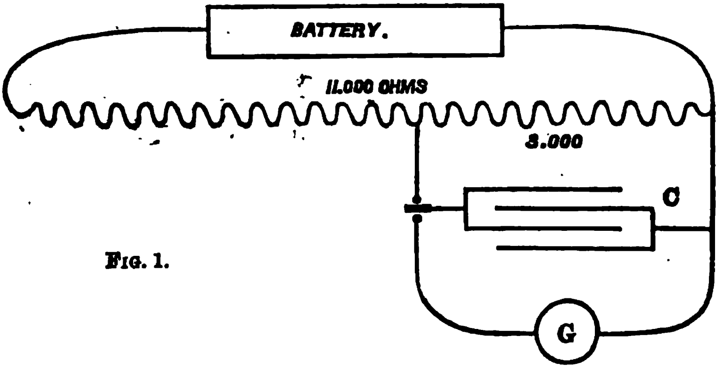


FIG. 1.

the condenser (C) to be measured was charged by joining its coatings one to each of two points in the circuit separated by an intervening resistance of 3,000 ohms; after which it was discharged through the ballistic-galvanometer (G), and the throw was read by the motion of a spot of light on a straight graduated scale: mean reading, 64·2 scale-divisions.

Next (fig. 2) the condenser was removed, and the galvanometer was joined in multiple arc with a coil of

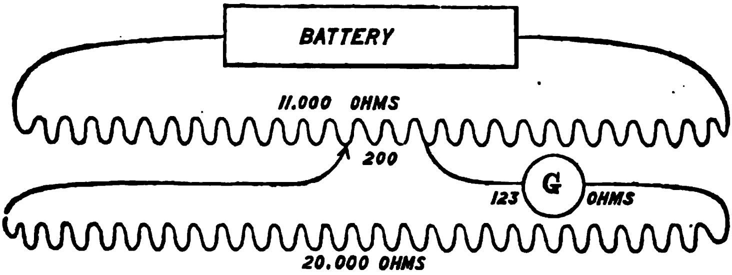


FIG. 2.

200 ohms forming part of the battery-circuit, the resistance of the galvanometer-branch being made up to 20,123 ohms. The galvanometer thus showed a permanent deflexion of 58·44 scale-divisions.

Time of one complete vibration of galvanometer-needle = 8·452 sec.

Determination of Damping. The galvanometer-needle having been set vibrating, the first elongation observed was 104 scale-divisions, and the twenty-fourth elongation was 45·5 scale-divisions.

$$\frac{1}{23} \cdot \log \frac{104}{45 \cdot 5} = \log 1 \cdot 0366.$$

Distance from galvanometer-mirror to centre of scale = 85·75 cm. 300 scale-divisions = 19·04 cm.

The deflections are so small that they may be identified with their *sines* or *tangents* without sensible error.

Calculate, from the above data, the capacity of the condenser.

Practical Examination.

Find the specific resistance of the given liquid—

(α) By high resistance galvanometer and condenser, or (β) by low resistance galvanometer and potentiometer.

Determine the thermo-electric power of the given junction at ordinary temperatures.

SUBJECT X. INORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or Alternative Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

$K = 39{\cdot}1. \quad Cl = 35{\cdot}5. \quad O = 16.$

1. Classify the following substances as elements and compounds: chalk, graphite, water, sulphur, iron, ammonia, oil of vitriol, chlorine, diamond, ozone. (8.)

2. How would you distinguish hydrochloric acid from nitric acid? Give the formulæ of the two acids, and describe the preparation of a salt of each acid. (13.)

3. Express in the form of equations the action of
    (1.) Heat upon mercuric oxide.
    (2.) Sulphuric acid upon common salt.
    (3.) Hydrochloric acid upon marble.
    (4.) Nitric acid upon copper.
    (5.) Steam upon red hot iron. (13.)

4. By what experiments can you prove that the air contains $\frac{4}{5}$ths of its volume of nitrogen? (9.)

5. How could you convert sulphur dioxide into sulphuric acid, and sulphuric acid into sulphur dioxide? (13.)

6. 100 cb.c of air are passed over red hot charcoal. How would you ascertain if the air was altered in volume or had experienced any alteration in properties? (13.)

7. How many litres of oxygen gas measured at 10° C. and 755 mm. can be obtained from 1 kilogram of potassium chlorate?

    (1 litre of oxygen at 0° and 760 mm. = 1·43 grams.) (15.)

8. What is meant by the term allotropy? Describe the various allotropic modifications of sulphur, oxygen, and carbon. (10.)

9. How would you prepare nitrous and nitric oxides? Give equations for the reactions, and state how you would recognise these bodies. (11.)

10. Explain what is implied by the following terminations:—*-ous*, *-ic*, *-ite*, *-ate*, and *-ide*, and give examples of their use. (10.)

11. How are the two oxides of carbon prepared, and by what tests may they be recognised? (12.)

12. Why is the flame of a taper extinguished in nitrogen gas and why does it continue to burn in air? (9.)

Alternative First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

21. A glass of water is exposed to the air. In time the water disappears into the air. How do you account for this? How could you prove that there is moisture in air? (13.)

22. Air is passed over red-hot iron. What change does this cause in the air and in the iron? (9.)

23. How could you show that the gas obtained by dissolving marble in hydrochloric acid is also contained in the breath? (10.)

24. Two samples of water are given to you. One is a hard water, and the other is distilled water. Describe two methods of distinguishing between them. (13.)

25. What is vinegar? How is it prepared? Vinegar is poured upon washing soda. What happens? (9.)

26. Ammonia is classed as an alkali. Why? Name some of the sources from which it can be obtained, and give its composition. (15.)

27. A piece of lead, a piece of copper, and some mercury, are separately heated in a crucible over a lamp. Describe what occurs in each case. (11.)

28. From what substances can starch be obtained? Of what is it composed, and how does it behave when boiled with water? (13.)

29. Name some commonly occurring compounds of sodium. How can you show that chlorine is a constituent of common salt? (10.)

30. What substances are contained in flour? How can they be separated, and what essential difference is there in their composition? (12.)

31. What is meant by saying that a solution is saturated? How would you prove that no loss of weight occurs when a substance is dissolved in water? (8.)

32. What are the distinguishing characters of cast iron, wrought iron, and steel? What is iron rust? (13.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt eight* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

Mg = 24. Ca = 40. K = 39·1. S = 32. O = 16. H = 1.
Na = 23. Cl = 35·5.

41. By what leading characters are the metals distinguished from the non-metals? (10.)

42. Explain what is meant by the atomic value or valency of an element, and arrange the following bodies according to their valency: Iron, Copper, Platinum, Phosphorus, Lead, Silicon, Calcium, Sodium, Chlorine, Zinc, Bismuth, Tin, Sulphur, Arsenic, and Carbon. (12.)

43. How many tons of oil of vitriol containing 70 per cent. H_2SO_4 are needed to convert 100 tons of salt into salt-cake? (12.)

44. Calculate the vapour density of ammonium chloride. By experiment it is found to be 13·345. How do you explain the difference between the calculated and observed results? Can you give any experimental evidence in support of your explanation? Do you know of any other similar cases? (15.)

45. How can you estimate accurately the amount of carbonic acid in atmospheric air? What causes tend (1) to augment and (2) to diminish its proportion in air? (11.)

46. How could you distinguish a chlorate from a perchlorate; a phosphite from a phosphate; a sulphite from a sulphate; an arsenite from an arsenate? (12.)

47. How is hydrofluoric acid prepared? Explain its action upon quartz, glass, zinc, and sodium carbonate. (12.)

48. Calculate the formula of a body which has the following percentage composition:—

Magnesium	3·98
Calcium	13·28
Potassium	12·99
Sulphuric acid (SO_4) ..	63·77
Water	5·98
	100·00

(15.)

49. Describe the method by which metallic lead is obtained from galena. What compounds of lead and oxygen are known? How are they prepared from metallic lead? (11.)

50. What is aqua regia? What compounds are formed by its action upon gold and platinum? (11.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

H = 1. O = 15·96. K = 39·03. Br. = 79·76. Ag. = 107·66.

61. Illustrate the value of isomorphism as a means of chemical classification. (13.)

62. An unknown quantity of potassium bromaurate, $AuBr_3KBr$ on being heated, left 9·92451 grams of a mixture of metallic gold and potassium bromide. The mass, on being treated with water, left 6·18997 grams of gold. The solution of KBr required 3·38540 grams of silver for total precipitation by Stas's method, and afforded 5·89143 grams of silver bromide. These data afford three independent values for the atomic weight of gold, which you are required to calculate. (18.)

63. What is the evidence that the molecules of most of the elements consist of two atoms? Name the bodies whose molecules seem to consist of only one atom. (15.)

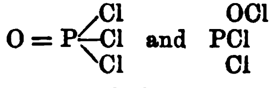
64. The following is an analysis of a sample of water:—

Total solids................	4·4	grains per gallon.
Nitrogen, as nitrates and nitrites	·017	„
Ammonia	·002	„
Albumenoid ammonia	·005	„
Chlorine	·800	„

Temporary hardness 0·1. Permanent hardness 2·4.
Total hardness 2·5.

Describe how such determinations are made, and give your opinion and the reasons on which it is based as to the suitability of this water for drinking purposes. (16.)

65. Phosphoryl chloride has been variously written



$$O = P\begin{cases} Cl \\ Cl \\ Cl \end{cases} \quad \text{and} \quad \begin{matrix} OCl \\ PCl \\ Cl \end{matrix}$$

Which is the more probable formula, and why? (17.)

66. Give some account of the modern views of nitrification, and describe the nature of the experiments on which they are founded. (14.)

67. What grounds had Mendelejeff for predicting the existence of the elements gallium, scandium, and germanium? (18).

68. Describe the methods of determining by volumetric analysis the following substances: phosphoric acid, peroxide of hydrogen, nitric acid, and sal-ammoniac. (16.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

Elementary Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

INSTRUCTION.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of your question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

1. You are required to prepare and collect some ammonia gas, and to show by experiment its most important properties. Describe in detail how you would do this, and give a sketch of the apparatus you would use. (15.)

2. The following reagents are added separately to a solution of copper sulphate :—Caustic potash, barium nitrate, ammonia ammonium sulphide. Describe what happens in each case, and represent the changes by equations. (10.)

3. A sample of lime, which has been exposed to the air, is suspected to contain carbonic acid. How could you ascertain and prove that such was the case? (10.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the elementary stage examination is confined to the qualitative analysis of two mixtures, each containing not more than two metals and one acid from the following list:

Lead, mercury, bismuth, iron, calcium, potassium, ammonium, carbonic acid, nitric acid, sulphuric acid, hydrochloric acid.

Two and a quarter hours are allowed for this part of the examination.

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Advanced Stage.

The two test substances supplied for qualitative analysis to candidates in the advanced stage consist of mixtures, each of which may consist of not more than two simple salts, the materials of which may be selected from the following list:—Potassium, sodium, ammonium, magnesium, calcium, strontium, barium, aluminium, chromium, zinc, manganese, iron, cobalt, nickel, arsenic, antimony, tin, cadmium, copper, bismuth, mercury, lead, silver, hydrosulphuric acid, hydrochloric acid, hydrobromic acid, hydriodic acid, sulphurous acid, nitric acid, chloric acid, carbonic acid, hydrofluoric acid, phosphoric acid, sulphuric acid.

Three and a quarter hours are allowed for this part of the examination.

Honours.

Three substances are supplied to each candidate in honours, two for qualitative and the third for quantitative analysis.

The two substances supplied for qualitative analysis consist of mixtures, which must be examined for all the bodies named above in the instructions for the advanced stage.

The substance for quantitative analysis need not be analysed qualitatively.

Quantitative Analysis.

Each candidate is furnished with a numbered bottle containing a powder in which iron has to be quantitatively determined.

The results must be expressed in grams of iron (Fe) in 100 grams of the powder. Fe = 56.

The candidate is recommended to weigh out, *accurately*, from 1 to 2 grams of the powder, for the purpose of analysis.

The candidate must not omit to place upon his worked paper the number attached to the bottle containing the powder he has analysed.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

Advanced Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

Whenever possible you are to express reactions in equations.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

1. A sample of hydrogen is supposed to be mixed with small amounts of aqueous vapour, carbonic acid, and oxygen. How would you free it from these gases? Give a sketch of the apparatus you would use. (10.)

2. Describe the reactions, giving equations, by which you would prove the presence of zinc nitrate in a solution. (10.)

3. How could you show that silica was contained in flint, phosphoric oxide in bone-ash, and lime and alumina in coal-ash? (15.)

SUBJECT XI. ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Whenever possible, you are to express the reactions by equations.

You are to give such numerical details as will show the mode of calculation.

The value attached to each question is indicated by a number placed at the end of the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

1. Describe the method of conducting an ultimate organic analysis of ethyl alcohol. (12.)
2. What do you understand by the term ethereal salt? Describe the preparation and properties of two such bodies. (10.)
3. What is the general formula of the paraffins? Describe their general properties. How may methane be obtained from inorganic materials? How may this gas be converted into chloroform and into carbon tetrachloride? (15.)
4. Describe the various methods of preparing acetic acid. How would you obtain the pure acid from a dilute solution? (9.)
5. How are the nitrite, nitrate, sulphate and acid-sulphate of ethyl prepared? Point out the analogy between these substances and the corresponding potassium compounds. (9.)
6. Describe the preparation of acetaldehyde, and the experiments which illustrate its most characteristic properties. (11.)
7. How would you obtain prussic acid from mercuric cyanide? From what body is it usually prepared? By what tests can very small quantities of it be recognised? (13.)
8. How can carbonyl chloride be prepared from its elements? Give some account of its properties and reactions. (13.)
9. How is ethyl iodide obtained? What is the percentage amount of iodine contained in it? (I=127.) (13.)
10. What reasons are there for the statement that cyanogen acts like an element? What is formed when this gas burns in the air? (10.)
11. How is methyl alcohol obtained? How may it be converted into formaldehyde and formic acid? (13.)
12. Why is carbon considered a tetrad element? (8.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *eight* questions.

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21. The nitrogen in an organic body has to be determined by the soda-lime process. Describe fully how you would do it, and state the changes which occur. (12.)

22. Describe the various steps by which ethyl alcohol may be converted into oxalic acid. (15.)

23. How is the combination of zinc with the radical ethyl obtained? What are its properties, and what action has water upon it? (10.)

24. How can urea be obtained synthetically from inorganic materials? Describe the reaction by which it was first artificially prepared. (12.)

25. By what reactions would you demonstrate that mannite is a hexhydric alcohol? What conclusions may be drawn from the action of nascent hydrogen upon grape-sugar? (12.)

26. Describe the preparation of uric acid from serpent's urine, and give the properties of the acid and its alkaline salts. (10.)

27. Explain fully why ethyl ether has the formula $\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$? (12.)

28. Calculate the vapour density of an organic liquid from the following data obtained by the Hofmann method.

Weight of liquid	0·338 gram.
Vol. of vapour	109·80 c.cm.
Temp.	99·50° C.
Bar.	746·9 mm.
Height of col.	283·4 „

(15.)

29. Give the composition of benzene. The relation it bears to phenol is said to be analogous to that which marsh gas bears to ordinary alcohol. Explain the grounds upon which this statement is based. What is the experimental evidence that toluene is methyl-benzene? (12.)

30. Describe what is meant by a compound ammonia. By what reaction is ethylamine obtained? Give its composition and properties. (10.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt six* questions.

$C=12. \quad N=14. \quad S=32.$

41. How is acetone prepared? Describe the modes of its reaction with the following bodies: nascent hydrogen, hydrocyanic acid, phosphorus pentachloride, hydrochloric acid, and ammonia. (16.)

42. Give an account of the bodies formed by the action of carbonic oxide upon potassium. (15.)

43. In what respects has a correspondence between chemical constitution and optical properties been traced in the case of organic compounds? (14.)

44. Calculate the formula of a body which has the following percentage composition:—

C —	15·80
H —	5·26
N —	36·84
S —	42·10
	100·00

The body is obtained by heating ammonium thiocyanate Name it and describe its chief properties and reactions. (18.)

45. Picoline and aniline have the same percentage composition. How are they obtained? State what you know respecting their constitution. (16.)

46. Give some account of thiophene and its principal derivatives. (13.)

47. What isomeric di-substitution products are formed from the chief mono-substituted benzene compounds by the action of (*a*) chlorine; (*b*) nitric acid; (*c*) sulphuric acid; where mixtures are obtained, state which isomeride predominates. (18.)

48. Give some account of the principal researches in organic chemistry associated with the names of Liebig, Dumas, Wurtz, Laurent, and Gerhardt. (17.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You must take the same stage in this written examination that you are taking in the examination in Practical Analysis in this subject.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *two* questions.

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1. Describe the preparation of ether by the continuous process, and give a sketch of the apparatus employed. (10.)
2. How could you show that oxalic acid heated with oil of vitriol yields equal volumes of carbon monoxide and carbon dioxide? (15.)
3. How would you demonstrate that strong sulphuric acid and dilute sulphuric acid act differently upon potassium ferrocyanide? (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *two* questions.

21. Describe the methods for determining the presence of chlorine, sulphur, and phosphorus in organic compounds. (15.)
22. How would you prepare stearic acid from suet? (10.)
23. Describe fully how to prepare absolute alcohol. What tests would you apply to prove that it was anhydrous? (10.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the Elementary Stage Examination is confined to the qualitative analysis of two mixtures, which may each contain not more than two of the following constituents, together with an inorganic base or bases which need not be determined:—

Formic acid, acetic acid, oxalic acid, tartaric acid, salicylic acid.

Two and a quarter hours are allowed for this part of the examination.

Advanced Stage.

The practical work for the advanced stage examination is confined to the qualitative analysis of two substances, each of which may contain not more than two organic bodies selected from the following list: Hydrocyanic acid, oxalic acid, acetic acid, tartaric acid, citric acid, salicylic acid, grape sugar, starch, morphine, and urea.

Any inorganic bodies present need not be determined.

Three and a quarter hours are allowed for this part of the examination.

Honours.

The examination in Honours consists of a qualitative analysis of the two mixtures supplied, and of the determination of the percentage of carbon and hydrogen contained in the organic substance distributed for this purpose.

The bottle marked (A) contains a substance in which the percentage of carbon, hydrogen, and oxygen (the latter by loss) is to be determined by Organic Analysis.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XII. GEOLOGY.

EXAMINER, H. W. BRISTOW, F.R.S., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are permitted to *attempt eight* questions only.

1. Write the names of six simple minerals which are of importance in the composition of rocks. (10.)
2. Mention the main differences between clay, marl, and loam. (10.)
3. What is conglomerate? Compare it with breccia, and state what each proves. (10.)
4. How does river-water differ from rain-water? (10.)
5. What is the nature of the evidence from which we arrive at the conclusion that an arctic climate formerly prevailed in the British Isles? (15.)
6. State the broad distinction between flagstones, slates and shales. (10.)
7. Explain the meaning of the term "drift," as used in geology. (10.)

8. Name the chief coalfields of England. Draw a section through one of them. (15.)

9. What is a trap-dyke? How does it differ from a fault or from a mineral vein? (10.)

10. What are the tests on which you would rely for judging of the age of sedimentary rocks? (10.)

11. Write in proper order, beginning with the newest, Carboniferous Limestone, Chalk, Cornbrash, Forest Marblo, Kimeridge Clay, Lower Greensand. (15.)

12. In what rocks do vertebrate animals, cephalopods, crustaceans, and land-plants first appear? (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are permitted to *attempt six* questions only.

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21. Explain the chief differences between the results of subaerial and marine denudation. (40.)

22. Explain the terms Pisolite, Cornstone, Anhydrite, Quartzite, Travertine, Tuff, Dolomite. (25.)

23. Explain the processes by which fossils have been preserved. In what British sedimentary rocks are they rare or absent? What explanation can you give for this? (40.)

24. What are alluvial deposits? What economic products are obtained from them in Britain? (25.)

25. In what sense is the word "cleavage" used by geologists and mineralogists? (15.)

26. Briefly describe the formation of a coal-seam, and of the strata with which it is associated. (15.)

27. Name the more important genera of *Carnivora* which are found in the bone-caves of Britain. How are these caves formed? (15.)

28. Under what circumstances do the outcrop and strike of strata not coincide? (15.)

29. State the division of the Animal Kingdom to which each of the following fossils belongs, and give its geological range:—Nummulites, Productus, Hippopodium, Trigonia, Murchisonia, Orthoceras (40.)

30. What class of fossils are of most importance in the identification of stratified rocks? Give reasons for your answer. (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are permitted to *attempt all* the questions.

The value attached to each question is the same.

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41. Compare the rocks which come between the Silurian and the Carboniferous in Devonshire, South Wales, and the South of Ireland.

42. Describe Serpentine. Mention the explanations which have been advanced as to the mode of its origin.

43. Describe the Elgin Sandstones, their geological age, and their fossil contents.

44. What are mineral veins? How have they been formed, and what are their usual contents? Illustrate your answer by a description of some special district.

45. Explain the mode of formation of gypsum and rock-salt. Describe the more important European deposits of each.

46. Give an outline of the geological history of the Spongidæ, or of the Ganoidei.

SUBJECT XIII. MINERALOGY.

EXAMINER, F. RUTLEY, ESQ.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt six* questions in all, of which the last question (No. 10) is obligatory.

The value attached to each question is shown in brackets after the question.

1. Arrange the names of the following minerals in a vertical column and in the order of their respective specific gravities, placing the heaviest at the bottom of the list:—Silver, Platinum, Barytes, Gold, Calcite, Copper. (14.)
2. Name three minerals which commonly crystallise in cubes and three which often occur in rhombohedra. (14.)
3. How does a rhombohedron differ from a cube, and how are the crystallographic axes situated in each? (14.)
4. State the chemical composition of the following minerals:—Celestine, Pyrites, Magnetite, Rock-salt, Pyrolusite, and Tinstone. (14.)
5. By what simple tests would you distinguish Realgar from Cinnabar, and Graphite from Molybdenite? (14.)
6. What minerals represent Nos. 2 and 7 of Mohs' Scale of Hardness? In what systems do these minerals crystallise? (14.)

7. What metals are respectively derived from Calamine, from Blende, from Galena, and from Cryolite? (14.)
8. Name four minerals from which iron is chiefly procured, and state the chemical composition of each of these ores. (14.)
9. Describe the construction of a contact goniometer. What discovery was made by means of such an instrument? (14.)
10. Name the three specimens placed before you, stating the chemical composition of each and the system in which each crystallises. Make also a blow-pipe analysis of the three powdered minerals supplied to you. State your results and how each result has been obtained. (30.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions in all, of which the last two (Nos. 29 and 30) are obligatory.

The value attached to each question is shown in brackets after the question.

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21. From what form is a scalenohedron derived, and how? (14.)
22. Explain the phenomena of pleochroism. (14.)
23. What is Malachite? In what system does it crystallise and in what condition does it usually occur? (14.)
24. State what you know concerning the minerals Asbestus, Brucite, Tremolite, and Aquamarine. (14.)
25. Describe the minerals Copper-Glance and Cuprite. (14.)
26. A crystal of Olivine shows the forms (010), (100), (001), (101), and (111). Give the corresponding symbols in Naumann's notation. (14.)
27. What is the chemical composition of the following minerals. —Wulfenite, Goslarite, and Crocoisite? (14.)
28. In what system does Apatite crystallise? Mention any varieties of this mineral. (14.)
29. Describe the six models placed before you, and name a mineral which crystallises in each of these forms. (14.)

30. Name the three specimens placed before you, and give the chemical composition and crystallographic system of each. Also make a systematic blow-pipe analysis of the three powdered minerals supplied to you. State your results, and describe clearly, but briefly, the means by which those results were attained. (30.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions in all, of which the last (No. 48) is obligatory.

The value attached to each question is shown in brackets after the question.

41. Give a short account of the Garnet Group. (14.)

42. What is Crocidolite? State what is known concerning Crocidolite-Catseye. (14.)

43. Describe the microscopic characters of Nepheline, Olivine, and Haüyne. (14.)

44. How does Linarite differ from Brochantite? (14.)

45. What is the chemical composition of Vanadinite? Describe any mineral isomorphous with it. (14.)

46. Give a brief description of the minerals included in the Epidote Group. (14.)

47. Explain the optical phenomena shown by a crystal of borax when a section normal to the acute bisectrix is examined in convergent polarised light. (14.)

48. Name the six specimens placed before you, stating the chemical composition of each and the system in which it crystallises. Also make a complete qualitative blow-pipe analysis of the three powdered minerals supplied to you. Describe clearly the results at which you arrive and the means employed in each case. (30)

SUBJECT XIV. ANIMAL PHYSIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR M. FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

The Examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

1. Where is the tricuspid valve placed? What is its form and structure? Describe how it appears when seen in a sheep's heart. Explain how it works in carrying on the circulation of the blood. (16.)

2. Where is the diaphragm placed? What important organs touch it on the one side, and what on the other? What structures pass through it, and through what part of it do they pass? What are the two kinds of tissue of which it is mainly made up, and how does each of these act in carrying on the work of breathing? (16.)

3. Where does the small intestine lie? Where and how does it begin, and where and how does it end? What is the general structure of its walls? What changes does food undergo in the small intestine? (16.)

4. What parts go to form the elbow joint, and how are they arranged to form the elbow joint? How is it that we are able to move the forearm on the arm in one way only, and that to a certain extent only? (16.)

5. What is the colour of venous blood when it flows from a vein, as for instance when a man is bled in the arm? What is the colour due to? If venous blood were spread out in a thin sheet over a large surface, would it change colour? If so, why? (9.)

6. What is the nature of the several foodstuffs present in milk? Why is milk so largely used, and so desirable an article of food? (9.)

7. Describe what may be seen by the naked eye or with the help of a simple lens when a long bone in a dried skeleton, the femur or humerus for instance, is sawn through lengthwise? How would a bone, taken from a recently dead body, and similarly sawn through, differ in appearance from the above? (9.)

8. How do the "red" and "white corpuscles" of the blood differ from each other? About how big is a red corpuscle and a white corpuscle in human blood? What is the name and nature of the fluid in which the blood corpuscles swim in a living blood vessel? (9.)

9. What is the medulla oblongata, and where is it placed? What is its form and general appearance? What are its more important functions? (9.)

10. When is the pupil of the eye large, and when is it small? How does it become large, and how does it become small? What purposes are served by these changes in its size? (9.)

11. What is the general composition of urine? What substances which are present in urine and so leave the body by the kidney, also leave the body by the skin or by the lungs? What substances present in urine do not leave the body in appreciable quantity by the skin or lungs? (9.)

12. When a man faints he generally falls down. Why does he fall down? (9.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

21. Describe the structure of a capillary blood-vessel, of a very small artery, and of a very small vein, and give an account of the flow of blood through these three kinds of minute vessels, such as may be seen in a transparent tissue like the web of a frog's foot. Explain why the flow though jerked and pulsatile in the arteries is steady and even in the capillaries, and why the rate of flow is so much slower in the capillaries than in the arteries or in the veins. (26.)

22. Give an account of the general structure of the liver, dwelling especially on the microscopic structure of a lobule. What differences would you expect to find as the result of chemical examination, or by other methods, between the liver of an animal which had been fasting for some days, and of one which had been well fed for some time? State the evidence that the liver carries on other work than that of secreting bile. (26.)

23. What are the essential differences between arterial and venous blood? What are the exact changes which take place in blood as it becomes venous in passing through the tissues and becomes arterial in passing through the lungs? To what extent may these changes be artificially brought about in blood outside the body? (16.)

24. Describe the structure of the pancreas. What changes occur in the pancreas some time after food has been taken? State the nature and composition of pancreatic juice, and explain briefly the changes which it effects on food. (16.)

25. Describe the arrangements and structure of the chain of sympathetic ganglia in the thorax and abdomen, explaining how it is connected with the spinal cord. To what structures do nerves pass from these ganglia, and what is known concerning the functions of these nerves? (16.)

26. In what parts of the adult body is cartilage present? Describe the general characters, and the microscopic structure of cartilage, mentioning the chief varieties of cartilage. To what extent is cartilage supplied with blood-vessels, and how is it nourished? (16.)

27. What are the physical conditions which determine that the visual image of an external object shall be sharp and distinct? What changes in these conditions lead to the visual image becoming blurred and indistinct though the retina remains unchanged? By what changes in the eye are we enabled to see distinctly at one time things far off and at another time things quite near, and what is the proof that these changes do take place, and do give us the power in question. (16.)

28. Describe the structure of an ordinary muscle, such as a muscle in a limb, as far as can be made out with the naked eye, and then state what further features may be made out by the use of the microscope. What is rigor mortis, and by what chemical changes is it accompanied? (16.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

The value attached to each question is the same.

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41. Give an account of "motor areas" or "centres," and "sensory areas" or "centres," in the cerebral cortex, dwelling especially on the evidence as to the part played by these "areas" or "centres" in the development of normal voluntary movements and normal sensations.

42. Describe the changes which take place in various secreting cells during and after secretion, and discuss the nature of these changes with reference to general questions concerning the constitution of "protoplasm" and the changes in protoplasm accompanying its activity.

43. Trace out as far as you are able the changes undergone in the body by carbohydrate material taken as food, and the effects which the material thus taken as food produces on the body.

44. Give an account of the mutual relations of the respiratory apparatus and the vascular mechanism, showing how they influence each other in ordinary and in extraordinary circumstances.

45. State and criticise the evidence as to the specific distinction of the several sensations caused by changes in the skin induced by contact, heat, cold, &c., and show to what extent the conclusions which you adopt are supported by histological investigation.

46. It is popularly stated that the body of man is wholly "renewed" once in seven years. Criticise this statement from the point of view of exact physiological knowledge.

Practical Examination.

1. State the nature, and point out the characteristic histological features, of *two* of the three mounted specimens A, B, C.

2. Make a preparation to show the nature and structure of *one* of the two tissues marked (*a*) and (*b*). Describe and draw your preparation.

3. Examine the fluid *x* with a view to finding out what substance or substances of physiological importance it contains.

Write short notes of the experiments you make, the results you obtain, and the conclusions you draw from them.

4. Demonstrate experimentally the inhibitory action of the vagus nerve on the heart of a frog.

SUBJECT XV. BOTANY.

EXAMINERS.—S. H. VINES, ESQ., M.A., D.Sc., F.R.S., and
D. H. SCOTT, ESQ., M.A., Ph.D.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced stages is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The Examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *six* questions.

You must *attempt* the first question on the paper. The remaining five you may select from any part of the paper.

1. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem,	Flower,	Pistil,
Leaves	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Stamens,	

(25.)

2. Describe the structure of a living parenchymatous plant-cell. What chemical elements enter into the composition (*a*) of the cell-wall, (*b*) of the protoplasm? (15.)

3. From what source and in what forms do plants usually absorb their nitrogenous food? Mention cases in which the nitrogenous food is absorbed from other sources and in other forms. (15.)

4. Give a botanical description of the part, in each of the following plants, which is commonly used as food: the potato, the onion, the turnip, and the carrot. (15.)

5. State generally what is the composition of a vascular bundle. Describe the longitudinal course of the vascular bundles in the stem of any Dicotyledon. (15.)

6. What is a placenta? Describe the placentation in the Cruciferæ, the Leguminosæ, and the Liliaceæ. (15.)

7. Give examples of plants which climb by means of tendrils, and explain how a tendril acts. (15.)

8. Explain, and illustrate by means of examples, the following terms relating to the stamens of flowers:—*tetradynamous*, *didynamous*, *diadelphous*, *syngenesious*. What is the meaning of the statement that the flower of the Orchidaceæ is *gynandrous?* (15.)

9. What is the botanical meaning of the term "Fruit"? Describe the structure of a plum, a strawberry, a blackberry, and an apple. (15.)

10. Describe the processes which lead to the conversion of an ovule into a seed, and state which is the difference between albuminous and exalbuminous seeds, giving examples. (15.)

11. Explain what is meant by Transpiration, and state how this process may be experimentally demonstrated. (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *six* questions.

You must *attempt* the *first* question on the paper, the remaining *five* you may select from any part of the paper.

21. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem,
Leaves,
Inflorescence,
Bracts,
Flower,
Calyx,
Corolla,
Stamens,
Pistil,
Fruit,
Seed. (25.)

22. Give a general account of the principal modes of branching of stems. What varieties of branching are illustrated by the following inflorescences; the raceme, the umbel, the corymb, the dichasial cyme? (15.)

23. A withered branch on a tree with deciduous leaves, retains its leaves in winter when the living branches have lost theirs. Explain the reason of this. (15.)

24. What is meant by "free-central placentation"? Describe the forms of free-central placentation occurring in the Primulaceæ, the Polygonaceæ, and the Compositæ respectively. (15.)

25. Describe and compare the structure of the staminal and carpellary flowers of Pinus. (15.)

26. Describe the structure, development, and mechanism, of the stomata. What is the effect of exposure to light upon the stomata? (15)

27. Describe the structural peculiarities of submerged water-plants as compared with allied land-plants. Give an explanation of these peculiarities. (15.)

28. Describe the process of fertilisation in any Angiospermous Phanerogam, giving a full account of the structure of the ovule at the time of fertilisation. (15.)

29. What is the structure of the cambium; how does it originate in the stem, and to what tissues does it give rise? (15.)

30. Describe, with diagrams, the structure of the flower in the chief British genera of Scrophulariaceæ. (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

You must *attempt* the *first* question on the paper, the remaining *four* you may select from any part of the paper.

The value attached to each question is the same.

41. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem,	Flower,	Pistil,
Leaves,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Stamens,	

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42. Describe the typical course of the development of the embryo within the seed of a Dicotyledon, and mention the most important variations from this type.

43. What is the "pericambium" of a root? State what is the function of the pericambium in relation (*a*) to the development of the lateral roots in Phanerogams, (*b*) to the growth in thickness of the root.

44. Describe the structure of the growing-point of the stem of an Angiosperm, and state in what respects it differs from that of a typical Fern, mentioning transitional forms connecting these two types.

45. What is meant by "root-pressure"? Explain fully how this pressure is set up, and mention cases in which the effect of the root-pressure is manifested in nature.

46. Give a comparative account of the early stages in the embryology of the Sporogonium in the Hepaticæ (Liverworts).

47. Give an account of the influence of light in inducing dorsi-ventrality in plant-members.

48. Give an account of the origin and distribution of the British Flora.

Practical Examination.

1. Make a longitudinal section of the stem of the Lime to shew the sieve-tubes.
2. Make a vertical section of the leaf of Asplenium, so as to pass through a sorus to show structure of leaf and sporangia.
3. Make a transverse section of the root of the Maize.

Each section is to be drawn and described. *One* section only is to be shewn in each case, and this is to be left in the field of the microscope.

4. Identify and briefly describe the macroscopic preparations I and II, and the microscopic ones A, B, C, D, and E.

15 minutes allowed for each preparation.

SUBJECTS XVI. AND XVII. GENERAL BIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR MICHAEL FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Elementary paper;

Or from the Advanced paper in Animal Morphology and Physiology;

Or from the Advanced paper in Vegetable Morphology and Physiology;

Or from the Honours paper in Animal Morphology and Physiology;

Or from the Honours paper in Vegetable Morphology and Physiology;

But you must confine yourself to one of them.

Where the values differ, that attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will, in all cases, secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in these subjects lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

1. State what takes place when you try (1) to grow "mustard and cress" in the dark, and (2) mushrooms in the dark, and explain as fully as you can the reasons of the results. (16.)
2. Describe the leaf of a chara, and explain how far it is like to and how it differs from a leaf of an ordinary plant, a rose leaf, for example. (16.)
3. State as exactly as you can how a hydra or fresh-water polype looks, and what you can make out about its movements and actions when you examine it with the naked eye, or with a simple lens. What further particulars concerning its structure and actions can you learn by the help of the microscope? (16.)
4. Describe the position and general structure of the organs by which the crayfish breathes, and explain how they act. Why can the crayfish live a long time out of water, and why would it soon die when placed in a closed jar filled with water which had been boiled? (16.)
5. What is the structure of the green stuff which is often seen on walls, trunks of trees, &c. How does it get there? How does it live? How does it spread? (9.)
6. On what things does a fresh-water mussel live? Explain how its food gets to its mouth. (9.)
7. What is the stamen of a flower, and of what parts is it composed? What is the use of stamens, and how can this use be proved? (9.)
8. Describe briefly the heart of a frog, and explain how it acts. How does it differ from the heart of a crayfish? (9.)
9. What is the structure of a prothallium of a fern? How does a fern give rise to prothallia, and how do prothallia give rise to ferns? (9.)
10. What is the nature of the nerve-ganglia of the mussel? Where are they placed, and how are they connected with each other and with the several parts of the body? (9.)
11. Explain the way in which the thin stem of a young sapling grows into the thick trunk of an old tree. (9.)
12. What is the nature and structure of the shell of a crayfish? What part of the skin of a frog corresponds to it? How is the crayfish able to feel through its shell? (9.)

SUBJECT XVI. ANIMAL MORPHOLOGY AND PHYSIOLOGY.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

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21. What are the chief points in which the organisation of a lamprey differs from that of a pike or a codfish? (26.)

22. Give an account of the general characters, structure of the mouth-parts, and modes of reproduction in the *Aphides* or plant lice? (26.)

23. What is the placenta? What functions does it perform? What are its chief forms, and in what groups of mammals are they found? (16.)

24. What are monads? What is known about their structure and modes of multiplication? (16.)

25. What are the essential characters of the *Polyzoa?* Give the names of any common kinds that you may have seen. (16.)

26. Describe the structure of a sea-urchin. (16.)

27. Give the essential characters of the different stages of metamorphosis of a butterfly. (16.)

28. Give an account of the process of yolk division. What is the structure of the cicatricula of a fresh-laid hen's egg, and how has it arisen? (16.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

The value attached to each question is the same.

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41. What is now known respecting the intimate nature of the process of fecundation in animals, and more especially of the events which follow upon the contact of the spermatic substance with the exterior of the ovum?

42. Describe the chief modifications of the oral appendages observable in the *Crustacea*, recent and extinct.

43. Describe the development of the vertebrate skull up to the time that the chondrocranium is complete.

44. What are the leading structural characters of the *Cetacea*? In what respects do the seals approach and differ from them? What is their range in time?

45. How are the different orders of insects related to one another morphologically, and what is known as to the order of their appearance in time?

46. What are the arguments in favour of and against the inclusion of the Tunicata among the Vertebrata?

SUBJECT XVII. VEGETABLE MORPHOLOGY AND PHYSIOLOGY.

EXAMINERS, S. H. VINES, ESQ., M.A., D.SC., F.R.S., AND D. H. SCOTT, ESQ., M.A., PH.D.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

The value attached to each question is the same.

51. Describe the primitive structure (as seen in transverse section) and the subsequent growth in thickness of the root of any dicotyledon.

52. State the evidence upon which the symbiotic nature of lichens has been established.

53. Describe the structure of a mature anther, and give an account of the development of a pollen-sac and of the contained pollen.

54. Give an account of the life-history of any Æcidiomycetous Fungus, and discuss the relation of these Fungi to the Ascomycetes.

55. Give an account of the optical properties of chlorophyll, and of its use in plants. What are the conditions upon which the formation of chlorophyll in the plant depends?

56. Enumerate and briefly describe the various parts of plants which are modified so as to serve as climbing organs. What advantages does a plant gain by climbing?

57. Describe the structure of the fertile cone of Equisetum, as well as that of one of the sporangiferous leaves, and of a spore. On what grounds may the cone be considered to be a flower?

58. Describe fully the process of indirect nuclear division.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

The value attached to each question is the same.

61. The characteristic difference between Phanerogams and Cryptogams is that the former produce seeds, whereas the latter do not. Fully explain the nature of the structural peculiarities upon which this difference depends.

62. Give a general account of the structure of the Siphonaceous Algæ (Siphoneæ), and describe fully the various forms of sexual reproduction observed among them.

63. Describe in detail the development of an antherozoid and of an oosphere in any plant you may select, and fully discuss the physiological significance of the various phenomena.

64. Discuss the comparative morphology of the sporocarps of the Rhizocarpæ (Hydropterideæ).

65. Explain what is meant by "Turgidity," and mention the conditions upon which this state depends. Discuss the mode in which turgidity is affected by external stimuli.

66. Give an account of the formation of starch grains (*a*) in parts of plants which are, (*b*) in parts of plants which are not, exposed to light, and point out what is the essential physiological difference between the two cases.

SUBJECT XVIII. PRINCIPLES OF MINING.

EXAMINER, H. BAUERMAN, ESQ., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The Examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt seven* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

1. What are mineral veins and beds, and what other terms are used for their description?

2. What is coal, and how is it found?

3. Describe with sketches the tools required for—
   (*a*) Hewing coal on a long-wall face; or,
   (*b*) Driving a level in a mineral vein.

4. How would you sink a small shaft of either circular or rectangular section, using timber to secure it?

5. How is coal brought from the working face to the pit-bottom in flat and inclined seams respectively?

6. Describe the working of a lode by overhand stoping.

7. How are mines kept free from water?

8. What different kinds of drawing ropes are used in mines?

9. What are safety lamps, and under what conditions are they safe?

10. How can a level be ventilated when it is beyond a main air-way?

11. Describe with sketches the construction of the horse-whim or gin.

12. How are metallic ores freed from waste minerals?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt seven* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

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21. What are the principal kinds of mineral deposits? Give an example of each.

22. In what formations are coals found besides the Coal Measures? Do such coals differ from those of the Carboniferous period?

23. Give an account of the method of putting down a bore hole, say 1,000 feet deep, and of the plant required.

24. Describe the method of working the thick coal or South Staffordshire.

25. Describe with detail sketches the construction of a skip-road in an inclined shaft.

26. Describe the endless chain system of haulage in levels.

27. What is the cause of acid water in mines, and what precautions are necessary for raising it?

28. How can compressed air be most economically applied to ventilation?
29. What arrangements have been adopted to prevent accidents from over-winding?
30. Describe the arrangement of the pumping engine and pit-work in a deep mine.
31. Describe the construction of an underground ventilating furnace.
32. How are rolls and stamps used for crushing minerals?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to *attempt six* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

41. Give an account of the South Wales coal basin, with details as to the nature, distribution, and method of working the principal seams.
42. Give an account of the distribution and association of tin ore in the more important tin-producing countries.
43. What methods have been used to determine the deviation of bore-holes from the vertical?
44. What power and appliances would you consider necessary for drawing 600 tons of coal in 10 hours from a pit 400 yards deep? Give some of the leading dimensions of plant (engines, boilers, &c.) that you would prefer.
45. What arrangements are necessary for renewing the wearing parts of mine pumps, and generally for keeping the pit-work in order?
46. What methods have been proposed for penetrating into mine workings when the ventilation is stopped?
47. Describe the construction of Darlington's or some similar boring machine.
48. What methods are adopted in the treatment of auriferous vein-quartz containing a small quantity of sulphides, when the latter is saved?

SUBJECT XIX. METALLURGY.

Examiner, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

General Instructions.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question and of the section before your answer.

You are to confine your answers *strictly* to the questions proposed; answers extending beyond the scope of the questions are disregarded by the Examiner.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

Instructions.

You are not to *attempt* more than *six* questions in this paper.

The value attached to each question is the same.

For a pass in the Elementary stage the student will only be expected to answer questions in *two* of the following *four* sections. At least two questions must, however, be taken from Section I.

For a First Class in the Elementary stage the candidate must answer questions in at least *three* sections. At least two questions must be taken from Section I.

Section I.

1. What is the elasticity of a metal? State how you would determine the degree of elasticity of a sample of steel.

2. If you wished to render (1) copper and (2) lead hard, how would you proceed?

3. For what purposes would you use a material which has the following composition:—

   Silica 97, Alumina 1·5, Lime 1·5.

4. What is meant by the statement that the calorific power of charcoal is 8,000?

Section II.

5. State what takes place when bright iron is exposed to moist air, and how may iron be protected from the action of the atmosphere?

6. Under what conditions will pure iron take up carbon, and what is the maximum amount it will retain?

7. Show by means of a sketch the method of "taking-off" the gases from a closed-mouth blast furnace.

8. How would you propose to work up the rough ends cut off from steel rails, or other steel scrap?

Section III.

9. Give two cases in which metals are separated from silver by volatilization.

10. Describe a wet method for separating silver from copper regulus.

11. If you had gold in solution as chloride, how, on a large scale, would you precipitate the gold?

12. When, during the smelting for copper, gold ores are added to sulphide of copper, in what products would you expect to find the precious metal?

Section IV.

13. When zinc is added to molten lead containing silver, what is the result?

14. In the blast-furnace treatment of impure lead ores, "slag," lead "speise," and "regulus" are produced. Explain these terms, and state what relative positions these products occupy in the furnace before tapping.

15. How would you purify zinc containing iron and lead?

16. What is the compound containing tin known as "hard-head"? How is it produced?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to *attempt* more than *six* questions in this paper.

The value attached to each question is the same.

For a pass in this stage the student will only be expected to answer questions in *two* of the following *four* sections; at least *two* questions must, however, be taken from Section I.

For a FIRST CLASS in this stage the candidate must answer questions in at least *three* sections; at least *two* questions must be taken from Section I.

SECTION I.

21. Give instances in which the colour of a metal is affected by small quantities of impurity.

22. What is meant by the expressions "mono-silicate" and "bi-silicate" as applied to a slag? Mention processes in which they would respectively be produced.

23. For what metallurgical operations would you employ (1) a long-flame non-caking coal, and (2) a short-flame caking coal?

24. Name the six specimens submitted to you.

SECTION II.

25. Describe a process in which a reverberatory furnace would be employed for converting pig iron into "mild steel." Give a sketch, in vertical section, of the furnace.

26. What is understood by the term "welding"? How does the property of welding depend on the physical condition of iron?

27. Show by means of a sketch, in vertical section, the arrangement of an hydraulic crane and ladle used in connection with the Bessemer process.

28. What amount of phosphorus does basic Bessemer slag contain? How would you propose to utilize such a slag?

SECTION III.

29. When a copper regulus containing both gold and silver is desilverized by the Ziervogel process, what becomes of the gold? State how you would extract the gold.

30. A sample of gold is found to contain both platinum and iridium. How would you separate these metals from the gold?

31. How would you proceed to treat an ore containing native silver and chloride of silver, with a view to the extraction of the silver?

32. If you wished to prepare alloys of gold having, for the purposes of the manufacture of jewelry, (1) light yellow; (2) greenish; (3) red tints, how would you proceed?

SECTION IV.

33. How would you smelt a copper ore mixed with 25 per cent. of galena, with a view to the extraction of both the lead and the copper?

34. Describe the method employed for the reduction of metallic bismuth from an ore containing disseminated sulphide of bismuth.

35. Show by a sketch, in vertical section, the arrangement of a Silesian zinc furnace with regenerative chambers.

36. State approximately the percentage composition of any four of the following alloys:—Brass, bronze, German silver, pewter, speculum-metal, gun-metal.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to *attempt* more than *eight* questions, and in these No. 51 must be included.

The value attached to each question is the same.

40. Why is the temperature actually obtained in a furnace lower than that indicated by theoretical considerations based on the composition of the fuel employed?

41. When sulphides are roasted in ordinary reverberatory furnaces, but little of the sulphurous anhydride so produced is utilized for the production of sulphuric acid. To what cause is this due, and how may the difficulties be overcome?

42. A sample of coal is found to contain sulphur. In what form does it occur, and to what extent will it pass into the coke obtained from the coal?

43. What are the difficulties connected with the electrolytic treatment of zinc ores? Describe such a method for the separation of zinc from zinc blende.

44. In the Claudet process for the desilverization of roasted copper pyrites, the silver is precipitated in the form of iodide. How is it that this process is commercially successful, *cuprous* iodide being also insoluble?

45. Many of the silver ores of the United States occur in admixture with large quantities of barium sulphate, from which they cannot well be separated by dressing. In smelting such ores with lead, what modifications in the blast-furnace treatment are necessary?

46. Show by sketches, in vertical section, the arrangement of a battery of stamps, and the usual accessory appliances which would be employed for collecting the gold present in quartz containing auriferous pyrites.

47. Some of the older heaps of copper slag at Swansea are known to contain nearly two per cent. of copper. In what way would you treat them in order to extract the copper, the ordinary Welsh method of copper smelting not being applicable?

48. What are the physical properties of pure iron? State how you would prepare a small quantity of very pure iron for purposes of research.

49. It has been observed that, at certain stages of the basic Bessemer process, the iron contains calcium and magnesium. How do you account for this, and how is it that these elements are not present in the finished iron?

50. What resemblances are there between the metallurgical treatment of (*a*) ores of iron and of nickel; and (*b*) ores of nickel and of copper?

51. Name and describe briefly the six specimens submitted to you.

SUBJECT XIX*p*. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Elementary Stage.

Three hours are allowed for this examination.

1. The candidate is required to prepare the alloy known as "Muntz metal" (or "yellow metal") from the copper and zinc given to him. He must deduce the percentage composition of the alloy he obtains from the weight of his product.
2. The sample is metallic lead. It is to be converted into oxide of lead which must not be fused. The candidate is to calculate the composition of the product from the increase in the weight of the lead resulting from the oxidation.

Note.—The candidate must place the number of his examination paper on the products he obtains, and hand them to the Superintendents of the examination, to be returned to the Department for examination.

SUBJECT XIX*p*. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Advanced Stage.

Four hours are allowed for this examination.

1. The candidate is required to estimate the amount of ash and of sulphur in the sample of coal given to him, and he is to state his opinion as to the character of the coal from the coke it yields.
2. The sample is an ore of iron; the percentage of iron is to be determined by a "dry" or a "wet" method.

Note.—The candidate must place the number of his examination paper on the coke he obtains in the *first question*, and hand it to the Superintendents of the examination, to be returned to the Department for examination.

Honours.

Eight hours are allowed for this examination.

11. The candidate is required to extract the copper and the silver from the "burnt" pyrites given to him. He is to roast the ore with salt, and, in separating the silver, he is to use the iodide of potassium sent. He is to state the amount of the copper and of the silver present.
12. The sample is bronze, and the candidate is required to determine the percentages of copper and of tin.

Note.—After weighing the iodide of silver he obtains, the candidate is to place the number of his examination paper on the packet enclosing the precipitate, and to hand it to the Superintendents of the examination, to be returned to the Department for examination.

SUBJECT XX. NAVIGATION.

EXAMINER, REV. J. B. HARBORD, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

In all cases the number of the question must be placed before the answer on the worked paper.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to *attempt eight* questions, viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Mention the chief considerations which show that the earth is spherical. Describe its figure more exactly, drawing a diagram. Define—longitude, parallels of latitude. What is the length of the straight line joining the north and south poles, and of the semicircle joining them? (12½.)

2. Define—course, nautical distance. State when the nautical distance between two places is also the shortest distance. Define—difference of longitude and departure between the place A from which a ship has sailed, and B that at which she has arrived; and draw a figure, A and B being both in the southern hemisphere. (12½.)

3 Describe the different parts of a mariner's compass, drawing a compass card with its divisions; name those only in the quadrant below S. and W. Define—true course, compass course. What causes their difference? Why is it necessary to be able to deduce one from the other? (12½.)

4. Write down the formulæ connecting—(1) course, departure, nautical distance; (2) course, difference of latitude, nautical distance; (3) course, departure, difference of latitude. Course=2¼ pts., diff. lat.=94 miles; find, from the traverse table, the values of departure and distance. What would be the course if the departure=94 miles, the distance being the same? (12½.)

5. How do you find at what rate a ship is sailing? Describe the instrument and process, and give an example as an illustration. (12½.)

6. What is the use of such observations as the following? What is the cause of the two angles differing?

Bearing of compass on shore from ship's compass.	Bearing of ship's compass from compass on shore.
N. 28° 30′ W.	S. 40° 10′ E.

What do you deduce from this particular example? (12½.)

Section II.

7. A ship sailed 39 miles W.S.W.; find, by calculation, the departure. (7.)

8. A ship sails 111 miles N.E. by E. from a place 5 miles due north of St. Abb's Head; latitude of St. Abb's Head is 55° 55′ N. Find the latitude in. (9.)

9. Find true course and distance, by middle latitude sailing, from Cape Comorin to Colombo.

Cape Comorin .. lat. 8° 5′ N., long. 77° 44′ E.
Colombo .. .. lat. 6° 57′ N., long. 80° 0′ E. (10.)

10. Find the latitude in and longitude in (by middle latitude method) having sailed from Cape Clear (lat. 51° 25′ N.; long. 9° 29′ W.), 320 miles S. 35° 20′ W. by compass; variation, 2½ pts. W., deviation, 3° E. (13.)

11. Find the compass course and distance, from A to B:—

Lat. A. ..	15° 30′ S.	Long. A. ..	155° 0′ E.
Lat. B. ..	25° 0′ S.	Long. B. ..	152° 30′ E.
Variation..	8° E.	Deviation ..	12° E. (13.)

12. A ship sails from a place in latitude 30° 10′ N., longitude 60° W., as follows:—

True courses.	Distances.
E. by N.	25 miles.
S.E.	12 „
N.N.W.	46 „
S.	64 „

Find the latitude in and longitude in. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* all or any of the questions.

21. Name and define the curve on the earth's surface which is always represented as a straight line on a Mercator chart. Is its essential property altered in this projection? Describe the construction of the Mercator chart. Give and prove the formulæ used in Mercator sailing. (25.)

22. Describe the two principal methods of ascertaining the deviation of the compass. What do you mean by sub-permanent magnetism? What is induced magnetism? In what positions of a ship has vertical induction the greatest effect? (25.)

23. What is the vertex of a great circle? Show how to find its latitude and longitude. State concisely the advantage of great circle sailing. Why can it only be followed approximately? In what cases is its advantage most apparent? (25.)

24. Having a glass which runs out in 25 seconds, construct a log-line to be used with it; the length of the nautical mile being 6080 feet. Describe Massey's or Walker's patent log. (20.)

25. Two ships, A and B, are on the same parallel in latitude 20° N., B being 236 miles due east of A; both sail due north till they reach the parallel of 45°. How many miles is B then due east of A? (15.)

26. Find, by Mercator sailing, the compass course and distance between Juan Fernandez (lat. 33° 40′ S.; long. 78° 58′ W.) and Easter Island (lat. 27° 10′ S.; long. 109° 25′ W.); var. 15° E.; dev. 3° W. (15.)

27. A plane passes through the centre of the earth and Amsterdam Island and Bouvet's Isle; find the length of the curve formed by the intersection of this plane with the surface of the earth intercepted between these two islands.

Amsterdam I., lat. 37° 48′ S.; long. 77° 25′ E.
Bouvets' I., lat. 54° 16′ S.; long. 6° 14′ E. (30.)

28. February 9th, 1887, at noon, C. Finisterre (lat. 42° 54′ N.; long. 9° 16′ W.), bore by compass E. by S. (ship's head N.W., dev. 4° 30′ W.), distant 10 miles; afterwards sailed as by following log account. Required the lat. in and long. in on February 10th at noon. Variation 24° W. (40.)

H.	K.	$\frac{1}{10}$ths.	Courses.	Wind.	Leeway Points.	Remarks.
1	5	2	W.S.W.	South.	1¼	Deviation 7° 50′ W.
2	4	6				
3	4	8				
4	5	0				
5	5	6				
6	5	4	North.	S.W.	0	Deviation 3° 50′ E.
7	7	0				
8	6	0				
9	5	6				
10	4	8				
11	4	2				
12	3	9				
1	2	8	West.	S. by E.	½	Deviation 10° W.
2	4	5				
3	3	7				
4	4	5				
5	5	2				
6	4	3	S. by E.	East.	1	Deviation 3° 40′ E.
7	5	4				
8	6	7				
9	6	0				
10	7	0				
11	7	2	N.W. by W.	N.E.	¼	Deviation 6° 50′ W.
12	7	5				

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* all or any of the questions.

41. Two steamers, A and B, are together in latitude 50° N.; they agree to rendezvous 2,100 miles due east, A steaming along the parallel at the rate of 7 miles an hour. Supposing B to steam along the great circle and arrive at the rendezvous simultaneously with A, find at what rate she must steam and her initial course. (50.)

42. Describe how the Traverse Table is constructed, and how and why it is of such practical use in navigation. Solve the following by the aid of the Traverse Table, explaining your process. A and B are two ships which leave the same place together; how far must B sail N.E. by E., so as to be due east of A when A has sailed 43 miles N.E. by N.? (40.)

43. Describe Napier's Deviation Diagram and Curve; explain and illustrate its uses. (50.)

44. State what is known as the "Law of Storms." Give the rule for determining the bearing of the centre. When a ship is caught in a cyclone what should be done? (40.)

45. A ship sailed by D.R. 89 miles S.S.E. in 13 hours, but it was found, by observation, that she had made good 73 miles S.E.; the log-line instead of being 51 feet was found to be only 48·5, and the 30 seconds glass to take 31 seconds to run out. Find the direction and rate of the current. Nautical mile =6080 feet. (50.)

46. Draw a sketch of a theodolite sufficient to indicate its principal parts, and state what adjustments must be made before commencing observations with the instrument. (40.)

47. Describe the method of making a running survey of a coast between two known positions. Draw a rough sketch to illustrate your description, the initial position being a harbour in the vicinity of which three conspicuous and conveniently situated hill tops had been determined on shore. What instruments would you use? (50.)

48. Construct a Mercator's chart on the scale of 1·8 inch to a degree of longitude, extending from 59° to 61° South latitude, and from 28° 30′ to 31° 20′ West longitude, taking out the meridional parts and drawing the parallels for every half degree. A ship sails from lat. 59° 40′ S., long. 30° 30′ W., S.E. by S. by compass 57 miles (deviation of compass 3° W.), and then west by compass (deviation 8° 30′ E.), 25 miles. The variation is 10° E. Lay down the true courses and take off the lat. in and long. in. (80.)

SUBJECT XXI. NAUTICAL ASTRONOMY.

EXAMINER, Rev. J. B. HARBORD, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

You are only permitted to *attempt eight* questions, viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Define celestial meridian, ecliptic, first point of Aries, rational horizon, declination. Illustrate each definition by a diagram. (12½.)

2. Explain, with figure, how diurnal time is defined, and show what is meant by sidereal time, apparent solar time, and mean solar time. What is the angle called which connects apparent and mean solar time? (12½.)

3. When an altitude of a limb of the sun is observed from the deck of a ship with a sextant, what are the corrections which have to be applied to obtain the "true altitude"? Explain fully and clearly, with a figure, "dip." (12½.)

4. Why is the sextant specially adapted for use at sea to measure angles with? What are the angles most frequently required to be observed? What are the uses of the following parts of the sextant—the horizon glass, the limb, the tangent screw, the vernier? (12½.)

5. Prove the rule for finding the longitude by chronometer and altitude of the sun. (12½.)

6. Define azimuth, altitude, amplitude; and illustrate your definitions by diagrams. What does the comparison of the true and compass bearing of the sun determine? What is required, in addition, to enable you to determine the variation of the compass? If a is the amplitude and d the declination of the body, l the latitude of the place, write down the formula connecting them. (12½.)

SECTION II

7. February 14th, 1887, in longitude 45° 30′ W., the meridian altitude of the sun's L.L. was 48° 10′ (zenith north); the index correction was + 1′ 40,″ and the height of the eye above the sea was 18 feet. Required the latitude. (8.)

8. March 20th, 1887, in longitude 180°, the meridian altitude of the sun's U.L. was 35° 20′ (zenith south). Index correction —2′; height of eye, 16 feet. Required the latitude. (10.)

9. January 12th, 1887, at 7^h A.M., mean time nearly, in latitude 31° 20′ N. and longitude 60° 30′ W., the sun rose by compass E. 28° 40′ S. Required the combined correction for variation and deviation. (8.)

10. February 10th, 1887, at 7^h 30^m A.M., mean time nearly, in latitude 25° 39′ N., and longitude 30° 34′ W., when the sun bore by compass S. 38° 40′ E., the observed altitude of the sun's U.L. was 9° 50′. Index correction—2′; height of eye, 25 feet. Required the variation, the deviation being 10° W. (12.)

11. June 4th, 1887, at 3^h 50^m P.M., mean time nearly, in latitude 20° 20′ N., and longitude by account 45° 55′ W., when a chronometer showed 5^h 32^m 58^s, the observed altitude of the sun's L.L. was 37° 58′ 55″. Index correction, + 2′ 10″; height of the eye, 18 feet.

    On May 22nd, at noon, the chronometer was slow on G.M.T. 1^h 12^m 35^s, and its daily rate was 2·5^s gaining.

    Required the longitude. (14.)

12. May 20th, at 8^h 30^m A.M., mean time nearly, in latitude 54° 30′ N., and longitude 3° E., when a chronometer showed 7^h 5^m, the observed altitude of the sun's L.L. was 37° 5′ 20″. Index correction, —3′ 10″; height of the eye, 20 feet. Required the error of the chronometer on G.M.T. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt all* or any of the questions.

21. September 24th, 1887, in longitude 80° W.; find what bright stars, given in the Nautical Almanac, will pass the meridian between the hours of 8 and 11 P.M.? At what time will the brightest of these stars be on the meridian, and at what distance N. or S. of the zenith, supposing the latitude of the place to be 10° S.? Draw a figure (projection on equinoctial) showing this star, the meridian, the mean sun, and the first point of Aries. (25.)

22. The altitude of a star is taken with a sextant and an artificial horizon. Show that the angle between the inclination of the index and horizon glasses of the sextant is equal to the altitude of the star. Draw diagrams illustrating your explanation. (20.)

23. Show how to calculate the parallax from the meridian zenith distances of a heavenly body observed at the same instant at two distant places on the same meridian. (20.)

24. Investigate the method of finding the error of a chronometer by a single altitude of a star. (15.)

25. June 17th, 1887, A.M., in latitude by account 51° 15′ N., and longitude 1° 30′ E., a chronometer showed $11^h\ 49^m\ 11^s$ (error on G.M.T. $3^m\ 46^s$ fast), when observed altitude of sun's L.L. near the meridian was 62° 0′ 10″. Index correction—30″; height of eye, 27 feet. Find the latitude by reduction to meridian, using estimated latitude. (20.)

26. March 12th, 1887, in latitude by account 38° 45′ N., the true altitude of Regulus was found to be 20° 22′ 30″, and at the same time the true altitude of Sirius was 30° 37′ 30″; both stars being east of the meridian. Required the true latitude. (30.)

27. June 28, 1887, at $5^h\ 30^m$ mean time nearly, in latitude 38° 42′ N., longitude 9° 39′ W., when a chronometer showed $5^h\ 31^m\ 0^s$, the bearing of the sun was observed to be N. 57° 30′ W. The error of chronometer on G.M.T. was $33^m\ 31^s$ slow, and the deviation of the compass 30′ E. Find the variation. (30.)

28. Define "observed distance," "apparent distance," "true distance," between two heavenly bodies. Explain clearly why, while the apparent place of the sun is nearer to the zenith than the true place, the apparent place of the moon is nearer to the horizon than the true place.

The observed altitude of the moon's L.L. was 26° 30′ 20″ on 1st March, 1887, at $2^h\ 15^m$ P.M., G.M.T. Index correction —1′ 40″; height of eye, 25 feet. Find the apparent and the true altitude of the moon's centre.

On 14th February, 1887, the true distance between the sun and moon was found to be 94° 20′ 10″, and the ship's mean time was $2^h\ 50^m\ 20^s$. Find the longitude. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt all* or any of the questions.

41. State shortly the principle of Sumner's method for finding the position of a ship by projection of lines of position.

November 29th, 1887, by D.R., the position of a ship was latitude 20° 40′ N., and longitude 36° 30′ W.; the correct G.M.T. by chronometer was $11^h\ 35^m\ 47^s$ P.M., and the true altitudes east of the meridian of Pollux and Sirius respectively 10° 48′ 30″ and 8° 19′ 20″. Find the longitude of four points to determine two lines of position, the most southerly points being in latitude 20°. Draw a rough diagram, and take off from it approximately the true latitude and longitude of the ship. (50.)

42. A ship is in north latitude; the sun's meridian altitude is 59° 30′, his declination north, and his setting amplitude W. 20° 30′ N. The declination being considered unaltered, find it and the latitude. (50.)

43. Investigate Ivory's method, with Riddle's extension, for finding the latitude and longitude by two altitudes and the Greenwich date. (50.)

44. What do you mean by the augmentation of the moon's semi-diameter? Prove that—

$$\text{Aug.} = 2\ \text{R. cosec.}\ (z'-p)\ \text{cos.}\ \left(z'-\frac{p}{2}\right) \sin\frac{p}{2}.$$

where R = horizontal semi-diameter, z' = apparent zenith distance, and p = hor. par. × cos. app. alt.

Find the augmentation of the moon's horizontal semi-diameter when the apparent altitude of the centre is 50° 30′, the horizontal parallax being 55′ 33·5″, and the horizontal semi-diameter 15′ 9·9″. (50.)

45. Explain, by help of a diagram, how tides are caused and the reason of the difference between spring and neap tides. Define "superior tide," "inferior tide." Distinguish between "the age of the tide" and "the lunitidal interval." The "establishment of the port" for London Bridge is given in the Nautical Almanac as $1^h\ 58^m$; explain clearly what this means, stating when it would represent the actual time of high water. Is there any other "establishment of the port"? If so, name and define it, and show how its value is obtained. (50.)

46. Find the time at which Jupiter will set, on May 20th, at a place in latitude 30° 45′ N. and longitude 29° 30′ W. (50.)

47. Describe the different methods ordinarily used for finding error of chronometer, viz., by time-balls, transit instrument, altitudes. Explain clearly what you mean by "the equation of equal altitudes." Having observed the altitude of a star east of the meridian, show how to find the time nearly when the corresponding equal altitude of the star west of the meridian is to be observed. (50.)

48. If a, p, and h are the true altitude, the polar distance, and hour angle of *Polaris*, prove that the following are successive approximations to the latitude of the place:—

(1.) $a-p\cos h$;
(2.) $a-p\cos h+\frac{1}{2}\tan a\,(p\sin h)^2\sin 1''$.

Find the latitude when

$a=46° 17' 28''$; $p=4644''$; $h=5^h 23^m 33^s$. (50.)

SUBJECT XXII. STEAM.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

1. Describe an experiment for ascertaining approximately the relation between the pressure and temperature of steam at a moderate pressure (say 10 lbs.) above that of the atmosphere. (15.)

2. In adapting the steam engine for driving machinery, Watt employed a steam cylinder with four valves for distributing the steam. Sketch a section through the cylinder of an engine of this kind, showing the valves, together with the steam and exhaust passages. Mark the valves by letters, and mention the order in which they are respectively opened and closed. (15.)

3. Sketch in section an ordinary locomotive cylinder with a D slide valve. Put the valve in its middle position. (15.)

4. How is an engine reversed when fitted with a single eccentric which is not keyed to the driving shaft? (20.)

5. Sketch and describe an ordinary form of piston for a stationary engine. Show the packing rings and the attachment of the piston rod. Name the materials employed in the construction of the several parts, and give reasons for employing the different materials. (15.)

6. What do you understand by the expansive working of steam? If steam be admitted into the cylinder of an engine at a pressure of 30 lbs. above that of the atmosphere (which is taken at 15 lbs. per square inch), and be cut off at one-third of the stroke, what is its pressure at the end of the stroke? (20.)

7. Sketch a longitudinal section of a Cornish boiler, show clearly the method of connecting the ends to the shell and flue plates, and mark the water level. Where is the feed water admitted, and for what reason? (20.)

8. Describe the water gauge for ascertaining the height of the water in a locomotive boiler. Show its position with reference to the fire-box of the boiler, and sketch a longitudinal section through the gauge. (15.)

9. Sketch a section through a surface condenser, showing the passage of the water and steam through it. By what means is the flow of water kept up? (20.)

10. Show the method of connecting the double-headed rail to the transverse sleepers of the permanent way of a railroad, and the method of joining the rails together. (15.)

11. What is the object of a separate expansion valve, and where is it placed? Sketch a section through a gridiron expansion valve. If such a valve has a travel of 1 inch, and the ports are 12 inches wide, how should the valve be constructed so as to give a maximum opening of ⅓ square foot? (20.)

12. What would be the indicated horse-power of a high-pressure, non-condensing steam engine, in which the mean effective pressure of the steam is 25 lbs. per square inch, the diameter of the cylinder 10 inches, and the length of stroke 18 inches, when running at 120 revolutions per minute? (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to *attempt more than five* questions.

The value attached to each question is shown in brackets after the question.

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21. What are *saturated*, *superheated*, and *wet* steam respectively? Why is there a loss of efficiency in using wet steam? Define a thermal unit, and explain the method of measuring the latent heat of steam. (25.)

22. If one pound of Newcastle coal develops 12,000 units of heat by its complete combustion, how much water at 60° F. should be converted into steam at 212° F. by the consumption of 1 cwt. of such fuel, assuming that there is no loss of heat during the operation? (30.)

23. Explain the effects produced by putting *outside* and *inside* lap respectively upon the slide valve of an engine. The outside lap is 1¾ inches, the lead is ⅛ inch, and the greatest opening for steam is 1½ inches, what is the travel of the valve, and how far is the valve from its middle position when the piston is just beginning its stroke? (30.)

24. The crank of an engine has a radius of 18 inches, the connecting rod is 6 feet long, and the number of revolutions made by the engine is 80 per minute. Find graphically or otherwise the velocity of the piston in feet per second when the crank has passed through an angle of 30° from the dead centre during the forward stroke. (30.)

25. Draw a theoretical indicator diagram for a condensing engine working expansively, and mark the scale on your diagram for an engine of 30 inches stroke supplied with steam at 30 lbs. absolute pressure, cut off at two-thirds of the stroke, and working with a vacuum of 12 lbs. Point out the assumptions which are made in drawing the theoretical diagram, and mark in dotted lines the actual diagram which you would expect to obtain if the engine were in good working order. (40.)

26. Sketch and explain the mechanism for opening and closing the steam valve of a single-acting Cornish pumping engine. (40.)

27. Describe the modified form of D slide known as a double-ported slide valve. Sketch a section through the valve and ports, showing the position of the valve when just opening for steam. When is it desirable to adopt a valve of this construction? (40.)

28. Find an expression for the thickness of the shell of a cylindrical boiler, the tensile strength of the material, the pressure of steam, and the diameter of the shell being given. If a cylindrical boiler 5 feet in diameter will support a steam pressure of 20 lbs., what should be the diameter of a boiler of like material, construction, and thickness of plate, for supporting a steam pressure of 100 lbs.? (35.)

29. Sketch and describe some form of slide valve which is fitted with a variable expansion slide at the back. (35.)

30. Describe, with sketches, the general construction of a boiler for generating steam at a high pressure, selecting that one of the three (land, marine, or locomotive) with which you are most familiar. (45.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to *attempt more than six* questions.

The value attached to each question is shown in brackets after the question.

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41. Describe, with sketches, the construction of a surface condenser. How are the tubes fixed? In a marine engine, fitted with a surface condenser, the steam enters the condenser at a temperature of 142° F., and is condensed into water at 120° F. How many pounds of circulating water, which enters at 60° F. and is discharged at 100° F., will be required for every pound of steam condensed? (50.)

42. Find the curve of position for a valve driven by an eccentric, the obliquity of the eccentric rod being disregarded. Hence deduce a method of constructing a valve diagram.
    Find graphically or otherwise the "angle of advance" and "eccentricity" where a valve is worked by a single eccentric (the obliquity of the rod being neglected), it being given that the inside lap is $\frac{1}{4}$ inch, the outside lap $\frac{15}{16}$ inch, the lead is $\frac{1}{4}$ inch, and the cut-off takes place at $\frac{4}{5}$ of the stroke of the piston, and find when the exhaust begins. (65.)

43. Describe, with sketches, the arrangement of some form of compound cylinder non-condensing engine, showing the connection of each piston with the crank and the valves and passages for distributing the steam. (60.)

44. Describe and explain Joy's valve gear, pointing out any special advantages in this form of valve gear as compared with the ordinary forms of link motion. (70.)

45. Investigate an expression for the efficiency of a heat engine working in a reversible cycle. Give an example of a cycle which is not reversible. (70.)

46. Write down Regnault's formula for the total heat of formation of steam at a given temperature, adopting Fahrenheit's scale.

It being observed that in a double-acting engine making 24 revolutions per minute, and indicating 125 h.p., the temperature of the steam in the boiler is 308° F., while that of the feed water is 75° F., the amount of dry steam passing into the cylinder per stroke is ·6 lbs., the amount of priming water ·025 lbs., and the amount of steam condensed in the jacket for each stroke is ·09 lbs., calculate the efficiency of the engine. Neglect any variation in the specific heat of water. (70.)

47. Make a sketch showing the construction of Giffard's injector, and explain the action of the injector.

If the volume of 1 lb. of steam in a boiler be 3·6 cubic feet and the volume of 1 lb. of water be ·016 cubic feet, compare the velocities with which steam and water would respectively issue from the boiler, and infer the kinetic energies of steam and water issuing under these conditions in the same time from equal orifices in the boiler. (65.)

SUBJECT XXIII. PHYSIOGRAPHY.

Examiners, PROFESSOR JOHN W. JUDD, F.R.S., and
PROFESSOR J. NORMAN LOCKYER, F.R.S.

General Instructions.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

The value attached to each question is indicated by the numbers in brackets.

1. Name four binary compounds of common occurrence, and state the elements of which each is composed. (15.)
2. What are the chemical elements present in pure air and pure water respectively? In what proportions are these elements present in each case? What is the difference between the condition in which the elements exist in air and water respectively? (15.)
3. State what you know concerning the difference of pressure in the atmosphere at different heights above the earth's surface. What is the cause of this difference? (15.)
4. Define energy and stress. (11.)
5. Why is mercury used in thermometers? (11.)
6. State what you know concerning the variation in the length of the day and night in different parts of the world at different times of the year. (11.)
7. What are the chief substances present in solution in the waters of the ocean, and whence are they derived? (11.)
8. What are snow-flakes, and how are they formed? (11.)
9. Explain how glaciers and rivers respectively carry materials from high grounds to lower ones. (11.)
10. What is a lava-stream? Of what does it consist, and how does it behave? (11.)
11. Into what simpler compounds can a piece of pure limestone be split up, and by what means? (11.)
12. Under what conditions is a country likely to have an abundant rainfall? (11.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *five* of the following questions.

The value attached to each question is the same.

21. Describe the planet Saturn.

22. Why is the influence of the moon on the tides greater than that of the sun?

23. What is the "Equation of time?"

24. How was the connection between comets and meteor-swarms established?

25. How is the length of a degree in a meridional arc measured?

26. What is the use of a transit instrument?

27. Explain the principles which enable us to determine the heights of mountains by observing the boiling point of water.

28. Describe the mode of formation of hoar-frost, and the conditions under which it takes place.

29. State the nature and mode of formation of the substances known as "travertine" and "sinter."

30. How are the deposits known as "Diatomaceous ooze" and "Radiolarian ooze" respectively formed?

31. What are volcanic dykes? How are they formed? State any peculiarities of their structure with which you are acquainted.

32. What is meant by sub-aërial denudation, and what are the chief agents engaged in it?

Honours Examination.

INSTRUCTIONS.

You are permitted to *attempt* all, or any, of the questions.

The value attached to each question is the same.

41. How does the constant of aberration enable us to determine the distance of the sun?

42. State what you know concerning the distribution of the earth's magnetism.

43. What are the terrestrial rocks which most nearly resemble the stony meteorites? Give an account of the mineralogical constitution and structure of these rocks.

44. How has the distribution of temperature in the oceanic waters at different depths been determined? What are the chief sources of error in such observations?

45. Give an account of the results which have been obtained by recent researches in connection with *one* of the following subjects:—
   (*a*) The spectra of sun-spots.
   (*b*) The formation of schistose rocks by pressure.

SUBJECT XXIV. PRINCIPLES OF AGRICULTURE.

Examiners, PROFESSOR HENRY TANNER, M.R.A.C., F.C.S., and PROFESSOR JOHN WRIGHTSON, M.R.A.C., F.C.S.

General Instructions.

If the Rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

Each question admits of an answer carrying an equal number of marks.

---

1. Enumerate the mineral or ash constituents of cultivated plants.
2. What descriptions of soil should you expect to find overlying and derived from (1) the London Clay; (2) the Upper Chalk; (3) the Lower Chalk?
3. Are stones useful in soils? If so, how?
4. In what ways do tillage operations render soils more productive?
5. Why are animal and vegetable refuse generally possessed of high manurial value? Give six good examples.
6. How do plants absorb their food from the soil and from the air? What do you understand by the phrase—"The food of plants"?
7. What are the conditions of successful germination of seed? Describe the changes which take place in a seed during the process of germination.
8. What is your opinion as to the relative values of starch, sugar, and fat as foods for fatting animals? To what uses are these substances put in the animal body?
9. What are albuminoids? In what stock foods are they most abundant? What purposes do they serve in animal nutrition?
10. What do you understand by the Norfolk rotation, and how may it most easily be converted into a five, six, or seven years' rotation?
11. Demonstrate that continuous dressings of nitrate of soda to the exclusion of other fertilizers, would tend to exhaust a soil. How might such exhaustion be prevented?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *six* questions.

Each question admits of an answer carrying an equal number of marks.

---

21. How does the presence of stagnant water in a soil influence the quality of the produce and the quantity grown?

22. How is the fertility of a soil improved by its possessing good capillary powers, and how may these be increased?

23. How have cultivated plants—such as wheat and root crops—been obtained, and what measures are necessary to maintain them in highly productive condition?

24. How does milk become sour, and how may this tendency be checked?

25. When are turnips, swedes and mangolds respectively, in their best condition for use as food, and how may this be explained?

26. What are the special merits of the practice of making ensilage?

27. What course of treatment favours the production of fat on the animal body?

28. What are the special points of character we seek to establish in pedigree animals, and how may they be secured?

29. How does change of soil and climate influence the utility of pedigree seeds?

30. What are the special advantages secured by spade-husbandry?

31. How do shelter and kindly treatment affect the character of milk?

32. Describe the structure of an egg, and the changes it undergoes during incubation.

33. How is the quality of fruit improved by bees?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to *attempt* more than *six* questions in this paper.

Each question admits of an answer carrying an equal number of marks.

41. Arrange the following foods for live stock in order of merit, and in so doing briefly give your reasons for the position assigned to each:—Linseed cake, clover hay, meadow hay, oat straw, barley straw, swedes, turnips, barley-meal, bean-meal, undecorticated cotton cake, decorticated cotton cake, bran.

42. Why do cattle and sheep require bulky food, while horses and especially pigs require concentrated foods? Give examples of dietaries suitable for each of these classes of live stock.

43. Give scientific reasons for the high estimation in which farmyard manure is held by farmers.

44. Contrast and compare grass, hay, and silage (sweet and sour) as foods for cattle.

45. Mention all the conditions which must be present in a soil to ensure high fertility.

46. Omitting all the conditions of fertility, you are next to enumerate all the indications of fertility, or of barrenness, in soils which you would take account of in walking over land.

47. Construct rotations of crops for light and for heavy soils, carefully selecting crops suitable for these two classes of land.

48. Show practically your knowledge of the chemistry of fertilizers by prescribing suitable mixtures of manures (1) for turnips; (2) potatoes: (3) clover; (4) wheat. In all these cases the soil must be assumed to be somewhat poor in the constituents most needed by these crops.

49. Enumerate the principal sources of phosphoric acid, potash and nitrogen available in the manufacture or the supply of artificial manures.

50. Describe the nature, causes, and appearance of the following diseases of farm crops:—(1) ear cockle (*Tylenchus tritici*); (2) ergot (*clavicips purpurea*): (3) smut (*Ustilago carbo*); (4) mildew (*puccinia graminis*).

SUBJECT XXV. HYGIENE.

EXAMINER, PROFESSOR W. H. CORFIELD, M.A., M.D. (OXON).

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours Paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

The same value is attached to each question.

1. Classify the food substances which do not contain nitrogen. How are they disposed of in the system?

2. What kinds of wells are there? What are the characters of the waters yielded by them?

3. Compare and contrast tea and cocoa as beverages.

4. How are movements of the air in rooms produced? How large an inlet opening for air is required for each person, and why?

5. What are the differences between air in towns and air in the country? What is the importance of these differences?

6. What animal parasites may be found on the surface of the human body? How may they be got rid of?

7. How should a dust-bin be constructed? What kinds of refuse should be put into it, and what not? How is it likely to become a nuisance?

8. At what periods of life is warm clothing most necessary, and why?

9. What are the disadvantages to health of living in crowded courts surrounded by higher buildings?

10. How are the breezes at the sea-side produced, and what effect have they on the healthiness of sea-side places?

11. Why is it important to keep the skin clean?

12. How would you treat a bad scald?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

The same value is attached to each question.

---

21. What are the most common adulterations of milk, coffee, cocoa, mustard, and beer, and what is the importance of each?

22. How may drinking-water be contaminated in a house after delivery?

23. How is the amount of aqueous vapour in the air determined? How is it expressed? What is the importance of it?

24. What is meant by a disconnecting trap? What are its uses?

25. What are the best known chemical methods for the treatment of sewage? How far are they successful?

26. What are the advantages and disadvantages of the different ways of covering the walls of rooms?

27. What is the best position for writing? What are the advantages of such a position?

28. What precautions is it necessary to take to prevent the spread of enteric (typhoid) fever?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

The same value is attached to each question.

41. Under what circumstances are marsh diseases found? What are their characteristics? What measures of prevention should be adopted?

42. Describe the manufacture of coal gas. What nuisances are liable to be produced in the neighbourhood of gas-works?

43. How much work in foot-tons can be expected from a diet consisting of cooked beef 10 oz., bread 24 oz., butter 1 oz., and potatoes 20 oz.?

44. What are the chief provisions of the Public Health (Water) Act, 1878?

45. What is the rationale of vaccination? Give the most important statistics of the results produced by vaccination and by re-vaccination.

46. What is meant by a life-table? How is it constructed, What are the effects of (1) a high birth-rate, and (2) emigration and immigration, on the death-rate of a town?

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EXAMINATION PAPERS

FOR

SCIENCE SCHOOLS AND CLASSES.

APRIL, MAY, AND JUNE, 1888.

SUBJECT I. PRACTICAL PLANE AND SOLID GEOMETRY.

EXAMINER, MAJOR G. S. CLARKE, C.M.G., R.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The constructions may be left in pencil, provided they are distinct and neat, and that the construction lines are shown. They must be strictly geometrical and not the result of calculation or trial. In the absence of those lines which are essential to a correct solution no marks will be awarded, however correct the result may appear.

Lines parallel or perpendicular to others may be drawn mechanically without showing any construction. Lines may be bisected by trial.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Questions marked (*) have accompanying diagrams.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Only *eight* questions are to be attempted.

A.

Plane Geometry.

*1. Given a scale of yards. Deduce from it a scale of feet to read to 1′·0″, and show 70′·0″. (8.)

*2. *aa*, *bb*, are given parallel lines; *p* is a given point. Throug draw a line cutting the given lines in points 1⅜" apart. (8.)

*3. The given figure represents a Maltese cross. Two dimensions a an angle are given. Draw the cross to a scale of ⅛" = 1'·0". (10.)

Solid Geometry.

4. A point 1·5" from both planes of projection is distant 3·25" fr another point 2·25" from both planes of projection. Obtain t projections of the two points. (10.)

*5. The given isosceles triangle, *abc*, is the plan of an equilate triangle, whose base *ab* is *in* the horizontal plane. Determine t height of the vertex C above the horizontal plane. (10.)

*6. *vv*, *hh*, are the traces of a plane parallel to the ground line; *a* i point *on* the ground line. Determine the length of a perpendicul drawn from *a* to the given plane. (10.)

*7. Draw the projections of a horizontal line lying in the given pla and 1·25" above the horizontal plane of projection. (10.)

*8. O*a* is the horizontal trace of a plane inclined at 65° to the ho zontal plane. O*i* is the plan of the intersection of this plane wi a second plane whose horizontal trace is O*b*. Determine and wri down the inclination of the second plane to the horizontal plane. (12.)

*9. *abcd* is a four-sided figure. Draw its plan when *bd* is horizont and *ac* inclined at 62° to the horizontal plane. (12.)

10. A hexagonal right pyramid, side of base 1¼", height 3¾", stands o the horizontal plane. Draw the plan and make a section by vertical plane the horizontal trace of which is a line through o angle of the base passing ¼" from the plan of the vertex. (14.)

*11. *abc* represents the plan of a wedge-shaped slice cut out of cylindrical cheese, whose height is equal to half the radius *ab*. Dra a plan of the slice resting with one of its rectangular faces on th horizontal plane, and construct an elevation on a line making 25 with the short sides of that face. (14.)

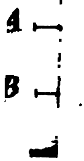
*12. The letter A as given is cut out of material ¾" thick, and stands on the horizontal plane. Draw the plan and make an elevation on a plane parallel to a diagonal of the rectangle at the top. (14.)

*13. Make a sectional elevation of the letter A (*Q.* 12) on a line passing through the plan of the point *b'*, and making 35° with the plan of the line *b'c'*. (14.)

Graphic Arithmetic.

*14. The given line x represents the sum of the two lines a and b divided by c $\left(\text{in other words } x = \dfrac{a+b}{c}\right)$. Determine and write down the length of the unit. (10.)

15. Draw a curve which will give the squares of all quantities from 0 to 6, taking ⅛" as the unit. (12.)



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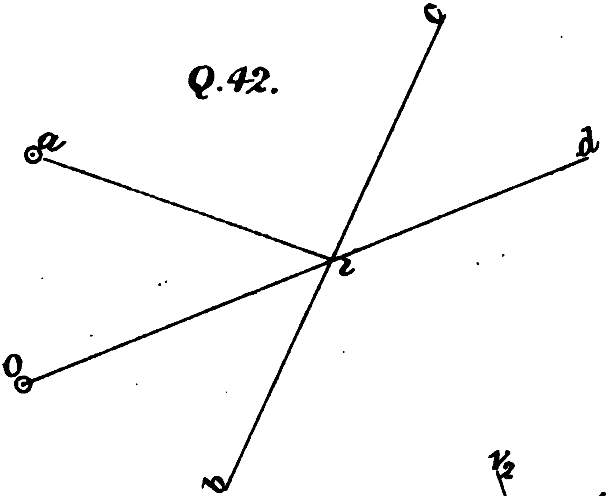

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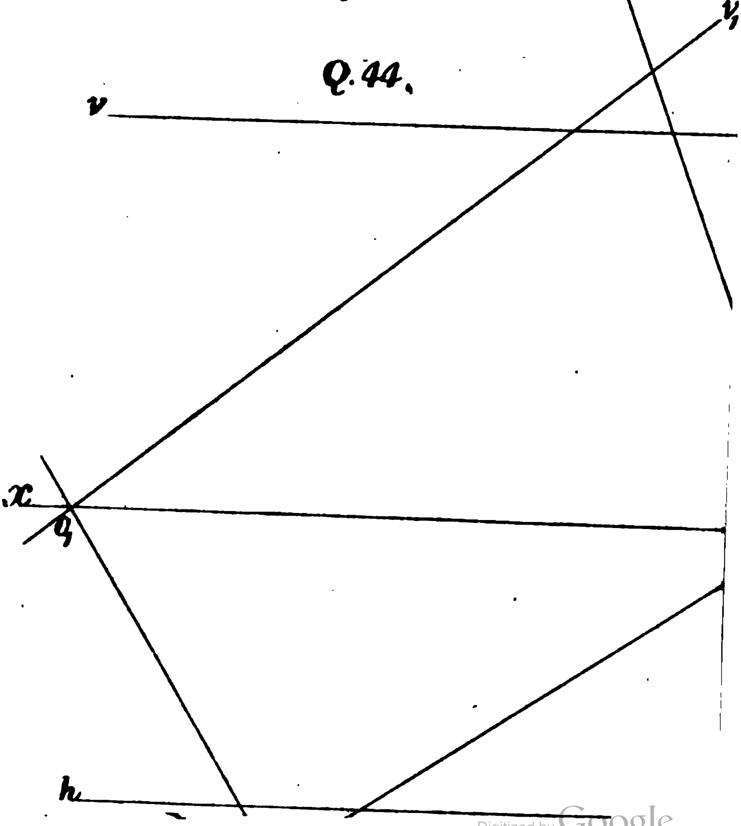

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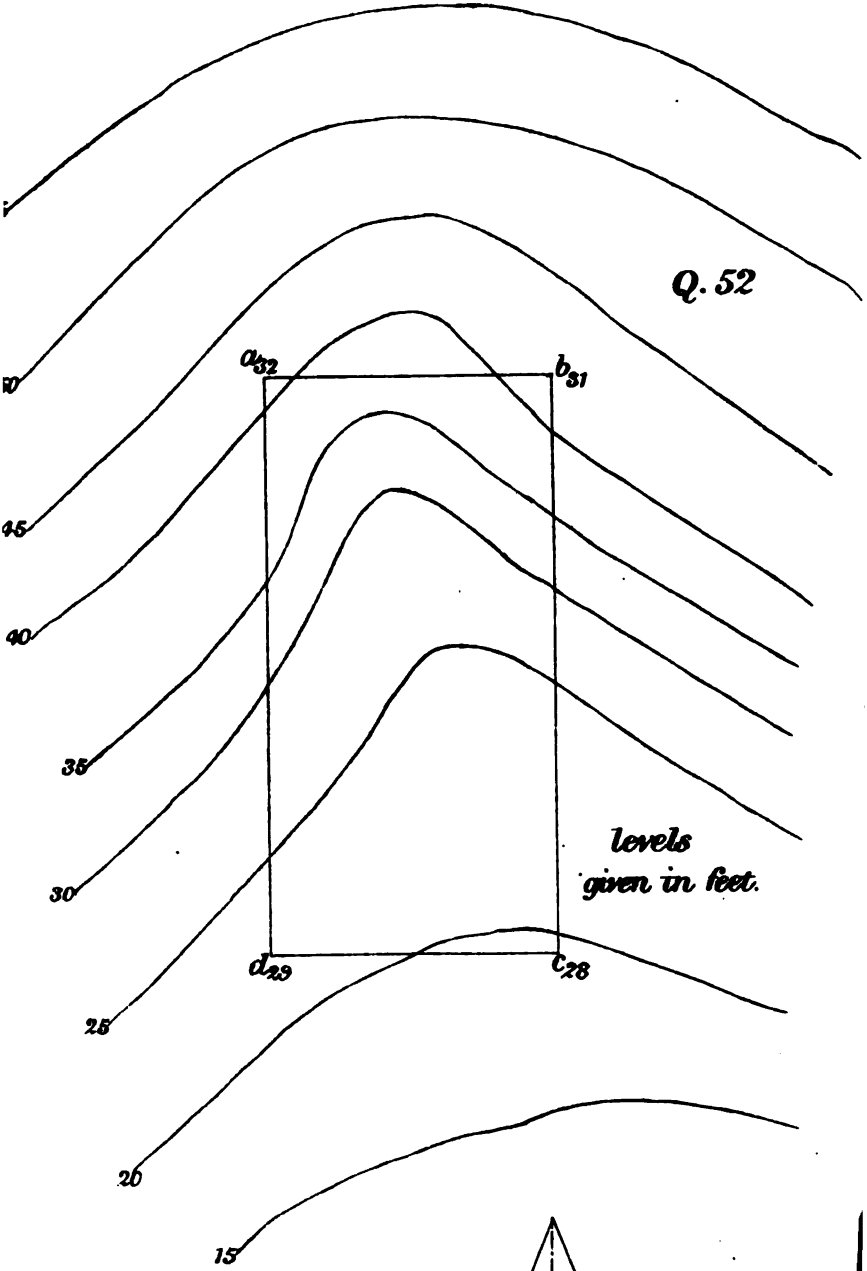
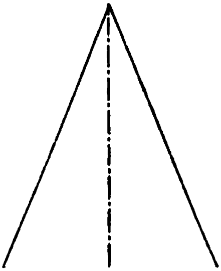


levels given in feet.



Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

Only *eight* questions are to be attempted.

B.

Plane Geometry.

*21. Divide the given line A into two parts, such that the sum of the squares upon them shall be equal to the square on the given line B. State what limitations are necessary as to the length of B in order that the problem may be possible. (16.)

*22. Two bars O_1a, O_2b, are pivoted at O_1 and O_2 respectively. At *i* they pass through a saddle which can travel along O_1a at ⅗ths the speed at which it can move along O_2b. Trace the locus of *i*. What is this curve ? (20.)

23. Describe a circle 4½″ in diameter. Suppose this circle to be given to you on the paper, and that you have only a pencil and a ruler with two parallel edges 1¼″ apart; show how the centre of the circle can be obtained. (16.)

Solid Geometry.

*24. Given two parallel lines, *a′b′*, *ab* ; *c′d′*, *cd* ; determine their distance apart. (18.)

*25. *a* is the plan of a point lying in the given plane *vt*, *ht*. Through *a* draw a line in the given plane *vt*, *ht*, parallel to the given plane *b*O*c*. (18.)

*26. Determine the intersection of the three given planes A, B, and *c*O*d*. (Unit 0·1″.) (20.)

*27. *oo* is a portion of the base of a right cone standing on the horizontal plane; v_{34} is the vertex. The portion *abcd* on plan is to be covered with paper. Determine the shape to which the paper must be cut. (Unit 0·1″.) (22.)

28. Given a point 1·25″ from the horizontal plane, and 1″ from the vertical plane, obtain the projections of a line 4·25″ long passing through the given point, and terminated by the planes of projection. What conditions as to the length of the line would render the problem impossible ? (22.)

*29. *a′b′c′d′*, *ad*, are the projections of a rectangular notice board supported by a vertical post *e′f′*. The board is blown over, in the direction shown by the arrow, till the post is inclined at an angle of 40° to the horizontal plane. Draw the plan of the notice board. (28.)

30. Two spheres, diameters 2·25″ and 1″, rest on the horizontal plane touching each other. Draw the plan of the complete locus of the centre of a sphere of 1·4″ diameter, touching both spheres. (24.)

***31.** The figured plan of an irregular triangular pyramid is given. A vertical cylindrical hole is bored through the pyramid as shown in plan. Make an elevation of the pyramid on a line parallel to AB. (30.)

***32.** A spherical segment rests on the top of a truncated hexagonal pyramid. The elevation and plan of the base are given. Draw the figure *twice* the given size, and determine the portion of the solid in shadow as seen in elevation. The direction of the parallel rays of light is indicated. (28.)

***33.** Draw the given figure (Q. 32) *twice* the given size, and make a sectional elevation of the solid on AB. (26.)

Graphic Statics.

***34.** Determine the line of action, and write down the magnitude of the resultant of the five given parallel forces acting in one plane in the direction shown by the arrows. (18.)

***35.** Obtain by construction a line representing the moment of the resultant of the two given forces P, Q, about the point O, using a scale of ⅛″ = 1 lb., and linear scale full size. (18.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

Only *eight* questions are to be attempted.

C.

Plane Geometry.

41. Divide an ellipse whose axes are 4″ and 2¾″ into *three* parts equal in area and perimeter. (40.)

***42.** *a* and O are given points; *bc* is a given straight line: Draw from O a line O*d*, which shall meet *bc* in a point *i*, such that the angles *aio*, *cid*, are equal. (35.)

***43.** Given two lines and a point *p*. Draw through *p* a line cutting the given lines in such a way that the intercepted portion is 1⅜″. (A curve may be employed in the solution.) (35.)

Solid Geometry.

***44.** The three given planes *vv*, *hh*, $v_1o_1h_1$; $v_2o_2h_2$, together with the planes of projection, enclose a solid. Draw the plan of this solid when the face contained in the plane $v_1o_1h_1$ is horizontal. (45.)

*45. Determine the projections of a sphere (radius ¾″) touching the given plane *mon*, and also the two given lines *a′b′*, *ab* ; *c′d′*, *cd*. (40.)

The mainmast of a steamer running at a speed of 6 miles per hour, is 55′·0″ high. The steamer is rolling 30° on each side of the vertical, and at the same time pitching 20° on each side of the vertical. The period of both roll and pitch is 10 seconds, and the motion takes place about the foot of the mast. Trace the plan of the locus of the top of the mast, starting from the vertical position. (Scale 1″ = 20′·0″.) (50.)

*47. *ab* is a line drawn on the floor of a railway truck moving at a speed of 5 miles per hour in the direction indicated by the arrow. A wheel whose diameter is 14′ 0″ is rolled across from *a* to *b* and back in 6 seconds. Trace the plan of the locus of a point on the circumference of the wheel, and make an elevation of this locus on a plane parallel to the direction of motion of the truck. Scale ⅛″ = 1′ 0″.) (45.)

*48. Draw the plan of a right cone, diameter of base 3″, height 3·5″, touching the given planes A and B, and so placed as to be above the plane A, and below the plane B. (Unit 0·1″.) (55.)

49. Make an isometric projection of an octohedron of 3·75″ edge, resting with one face on the horizontal plane. (N.B. An isometric scale need not be used.) (40.)

*50. A truncated hexagonal pyramid, height 1·5″, rests on a square block, height 0·5″. The plans of both solids are given. Determine the shadow cast upon the horizontal plane, and a vertical plane standing on *xy*. The source of light is a point whose plan is *s*, and height above the horizontal plane 1·25″. (55.)

*51. A twisted surface is traced by a horizontal line meeting the given lines *ab*, *cd* ; *efg* is the horizontal trace of a conical surface whose vertex is *v*. Draw the plan of the intersection of the two surfaces, and also an elevation on *xy*. (Unit 0·1″.) (50.)

*52. A portion of ground contoured at 5′ 0″ levels is given. A plane surface *abcd* has to be formed partly in cutting and partly in embankment. The side slopes are 45° in cutting and in embankment. Draw the contours of the completed earthwork. (Scale 1″ = 20′ 0″.) (45.)

*53. The elevation and the plan at AB of a symmetrical tower are given. Make a perspective view of the tower, taking *xy* as the ground line of the picture plane, and *s* as the plan of the station point which is on a level with *ab*. (55.)

Graphic Statics.

*54. A horizontal beam *ab* is so loaded that the vertical ordinates of the figure above it represent the intensity of the load at any point. Determine the point about which the beam will balance. (40.)

*55. *ab* is a rigid rod, *ac* a tie. At what point along *ab* must a weight of 50 lbs. be suspended in order to produce a tension of 29 lbs. in *ac* ? (40.)

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

EXAMINERS, PROF. T. A. HEARSON, M. INST. C.E., and J. HARRISON, ESQ., M. INST. M.E., ASSOC. M. INST. C.E.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are expected to prove your knowledge of machinery, as well as your power of drawing neatly to scale. You are therefore to supply details omitted in the sketches, to fill in parts left incomplete, and to indicate, by diagonal lines, parts cut by planes of section.

No credit will be given unless some knowledge of projection is shown, so that at least two views of one of the examples will be required properly projected one from the other. The centre lines should be clearly drawn. The figured dimensions need not be inserted.

Your answers should be clearly and cleanly drawn in pencil. No extra marks will be allowed for inking in.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

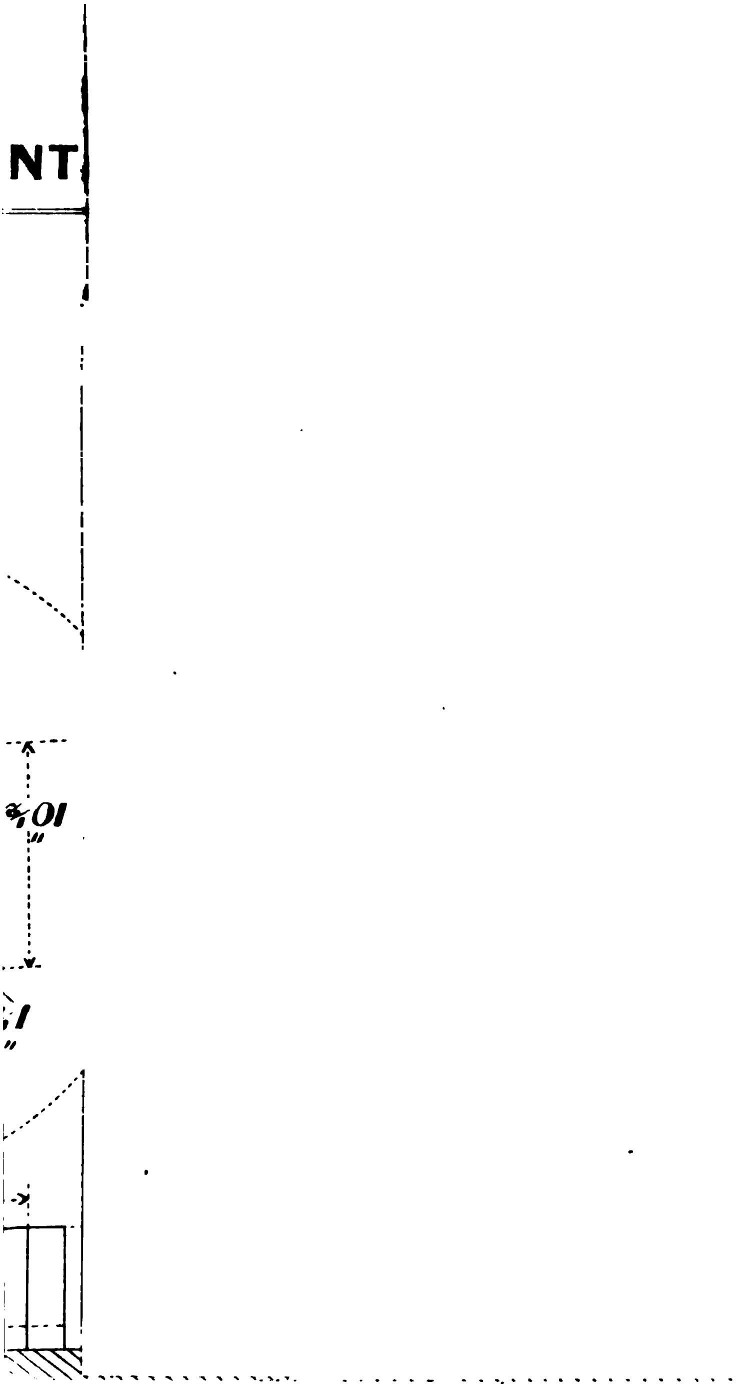
The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Answer briefly any three, but not more than three, of the following questions, and draw two, but not more than two, of the examples.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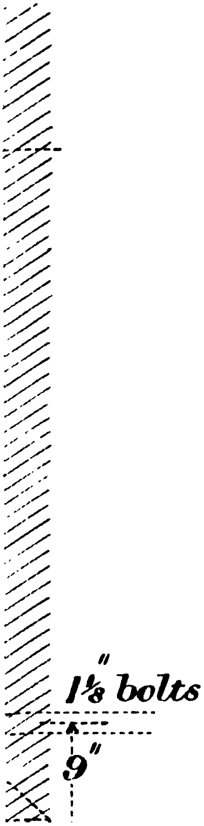

1⅛" bolts
9"

Questions.

(*a.*) Give sketches showing how the separate lengths of a line of shafting may be connected together. (8.)

(*b.*) What is the object of using chipping or facing strips in fitting up machine parts? Give one or two examples. (8.)

(*c.*) Give sketches showing how you would grip and drive a round iron bar for the purpose of turning it between the centres of a lathe. (10.)

(*d.*) Explain the action of the governor shown in Example 1. (10.)

(*e.*) Describe in detail how the mud-hole door in Example 2 is removed for the purpose of cleaning the boiler, and how it is replaced and the joint made steam-tight. (10.)

(*f.*) Describe how the parts of the spur wheel in Example 3 are put together, and explain why the wheel is made in segments. (10.)

Examples to be Drawn.

Diagram D.

1. Loaded governor for small gas engine. Draw and complete the two views, partly in section as shown. Scale full size. (35.)
2. Mud-hole mouth-piece for Lancashire boiler. Draw and complete the two views shown. Scale $\frac{3}{8}$ths. (35.)
3. Point for segments of large spur wheel. Draw and complete the views shown. Scale $\frac{3}{16}$ths.
   NOTE.—As the radius of the wheel is too large for your instruments, the circumference at the joint may be set out straight, as in a rack. (35.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on p. 8.

Answer briefly any three, but not more than three, of the following questions, and draw the example given.

Questions.

(*g.*) Show by sketches the construction of a hydraulic piston suitable for high pressures. (20.)

(*h.*) Give two views of a tooth of a mortice spur wheel, showing how it is fitted into the rim of the wheel and held in position. Under what circumstances would you use mortice wheels? (15.)

(*k.*) Show how the cylindrical shell of a Lancashire or Cornish boiler is connected to the flat end plates. (20.)

(*l.*) What are the special properties possessed by brass which make it of value in machine construction? Illustrate your answer by two or three examples. (15.)

(*m.*) Explain why an eccentric sheave is frequently made in two parts. Give sketches showing how the two parts are secured together, and how the sheave is fixed to the shaft. (15.)

(*n.*) Sketch an arrangement for screwing up simultaneously the several nuts of the gland of a large stuffing box. (20.)

Example to be Drawn.

Diagram E.

Wall fixing for vertical and horizontal shafts. Draw and complete the two views shown. Also give a sectional elevation on AB, looking in the direction of the wall.

The bevel wheels may be drawn in section; do not project the teeth. If time permit, draw the pedestal and details of the footstep bearing. Scale 1½ inches to the foot. (140.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on p. 8.

You are permitted to answer only *eight* of the following questions.

The sketches required in answer to these questions may be in pencil, and need not be drawn to scale, but should be neat and in good proportion. The written answers must be in ink, and may be written on foolscap paper, which can be obtained on application to the superintendents of the examination. Each sketch should be made in immediate connexion with the answer to which it refers.

---

41. Give full details of the construction of a large copper steam pipe. Estimate the required thickness of a copper pipe 10″ diameter for a working pressure of 150 lbs. per square inch. (20.)

42. Describe fully, and illustrate with sketches, the preparation of a mould for casting a large cylinder for a steam engine. (25.)

43. Describe, and give sketches showing, the process and special tools employed in boring a cylinder of large diameter. Estimate the time required to bore, (including the finishing cut,) a cylinder 5′ diameter and 5′ long. (25.)

44. Give sketches showing the construction of a bogie, and how it is connected to the frame of a locomotive engine. Explain the use of a bogie. (20.)

45. A pair of wheels of a railway waggon is required to carry six tons, the distribution of which may be four on one wheel and two on the other. The centres of the axle boxes are 6′ 2½″ apart, and the gauge of the rails is 4′ 8½″. Allowing a working stress of five tons per square inch, determine the required diameter of axle, 1st, at the wheel seat; 2nd, at the centre of length. (25.)

46. With the aid of sketches describe the hauling gear for the cage of a mine, showing how overwinding is avoided, and descent of cage prevented in the event of failure of rope. (20.)

47. Give sketches and a description of a hydraulic lift, showing an arrangement by which the diameter of the lift ram may be made independent of the available water pressure, and also how the weight of cage and ram may be balanced by hydraulic pressure. (25.)

48. Quote a formula for the hoop tension in a thick hollow cylinder subjected to an internal fluid pressure. The external diameter of a hydraulic press cylinder is 12″, and the thickness is 2″. Determine the hoop tension at the internal and external surfaces, when the internal pressure is two tons per square inch. (25.)

49. Give sketches and describe the construction of a sight feed lubricator for supplying the piston and valves of a steam engine with oil. Describe how it is used, and explain its advantages. (20.)

50. Describe and illustrate with sketches the construction of the thrust bearing of a screw propeller shaft, showing how it is rigidly secured to the ship, and how provision is made for adjusting its position, and for keeping it cool. (20.)

51. Obtain the expression—

$$\delta = 0{\cdot}4\, k \frac{p}{f} \frac{d}{d'}\, d, \text{ (very approximately,)}$$

for the diameter of the bolts for a cylinder cover:

where δ = diameter of bolts,
$k\delta$ = circumferential pitch of bolts,
p = maximum intensity of pressure in cylinder,
f = stress allowed on material of bolt,
d = internal diameter of cylinder,
d' = diameter of bolt circle.

Give some information as to the values of k and f which are suitable under different circumstances. (25.)

52. A long steel tie bar, or stringer, of section 8″ by 1″, is constructed in lengths which are riveted together. Design a suitable joint, and estimate its efficiency. (25.)

53. In the construction of a boiler a semi-cylindrical top and bottom are joined by flat sides, which are supported by two rows of horizontal stays, extending across the boiler, as shown in Fig. 1. Determine the vertical pitch p of the stays, in terms of l, the height of the flat sides, for least bending moment on the flat plates. (25.)

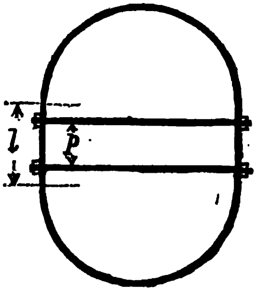


Fig. 1.

54. A crane is constructed as shown in Fig. 2. Draw the reciprocal stress diagram for determining the stresses on the jib, stays, and crane post, and the thrusts on platform, and footstep bearing. (25.)

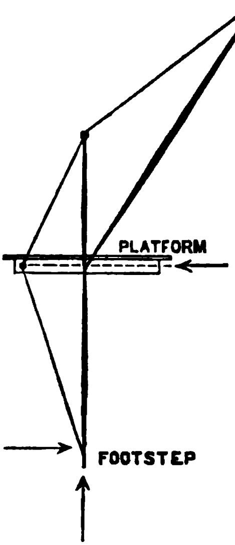


Fig. 2.

55. Obtain a formula for the total stress at any point of the transverse section of a piece which is subjected to a bending moment, in addition to a longitudinal thrust or pull.

A piece of T-iron consists of a web 4″ deep and ½″ thick, and a flange 2″ wide and ½″ thick. It is subjected to a longitudinal pull, the line of action of which passes through the centre of depth of web. Determine in what ratio the piece is weaker than if the line of action of the load passed through the centre of area of the T section. (25.)

56. State what effect the existence of lateral stresses is supposed to have on the capability of material to sustain a longitudinal stress with only elastic deformation. A thin spherical and a thin cylindrical shell, each of the same diameter, are constructed of steel, the ends of the cylinder being completely stayed by longitudinal stays: compare the internal pressures which they will each sustain. (25.)

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

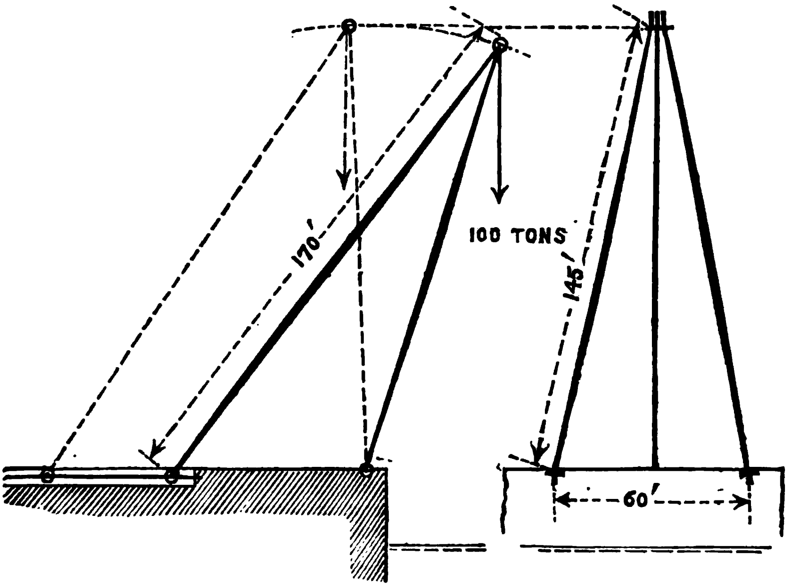
Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at home. The drawings, &c. are to be sent by post to the Secretary, Department of Science and Art, London, S.W., on or before the 23rd of June. The postage need not be prepaid. The drawings should be as fully detailed as possible, and carefully dimensioned. Some marks will be allowed for inking-in and colouring, but more credit will be attached to good proportion and fulness of detail.

The subject for design is a set of sheer legs capable of lifting a weight of 100 tons into a vessel from the shore.

The lengths of the three legs, and the distance apart of the feet of the two forelegs, are shown in the following figure. The back leg is to be provided with a travelling foot, having a traverse of 40′. The maximum overhang required is 40′.



(*a.*) Draw a stress diagram, and determine the greatest tension and thrust on the members of the structure.

(*b.*) Design and draw the upper joint of the three legs.

(*c.*) Design and draw the lower joint of one of the forelegs.

(*d.*) Design and draw the travelling foot and guides.

(*e.*) Give a section and elevation showing the construction of each of the legs at about the centre of length.

(*f.*) The weight of 100 tons is to be lifted by means of two pairs of pulley blocks, with two wire ropes. Design and draw one of the blocks.

(*g.*) Give particulars of the engine required for traversing the back leg.

(*h.*) Estimate the efficiency of the hoisting tackle, and give particulars of the gear and engines required for lifting.

Give all the calculations which you make.

The following voucher must be signed and returned with the worked drawings :—

I, ______________________________

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Machine Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed)______________________

No.__________

The above number must be quoted on each separate sheet of drawings worked by you.

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E. (Ret.).

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

All drawings must show a correct knowledge of construction. Neat and accurate drawing to scale is required. Where only sketches are asked for the proportions must be approximately correct, though extreme accuracy, as in drawings to scale, is not necessary. The drawings may be left in pencil, provided they are distinct and neat. No extra marks will be allowed for inking in.

You are to confine your answers *strictly* to the questions proposed.

Put the number of the question before your answer.

Answers in writing must be as short and clearly stated as possible, and close to any figures to which they may refer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

Questions marked (*) have accompanying diagrams.

The Examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *seven* questions.

*1. Cross section of a stone to be formed into a window sill.

Draw, to a scale of ¼, the finished cross section, at the centre, showing it weathered, throated, and grooved for a metal tongue. (11.)

*2. Cross section of six courses of a 2½ brick wall built in English bond.

Draw, to a scale of an inch to a foot, making any alteration you may think necessary. (11.)

*3. A and B are sections through a wooden floor girder and a bridging joist.

Draw, to a scale of ⅛, two cross sections of the girder, showing the joist notched to it in the one case, and cogged to it in the other.

The cogged joint to be marked C, and the notched joint N. (11.)

*4. A is the section of a stone string course. B is a part cross section of a coursed rubble wall built of a thin bedded stone occurring in layers of from 4″ to 8″ thick.

Draw B to a scale of 1¼″ to a foot, showing the stones, and inserting the string course at *a*. (11.)

5. Explain by sketches the following terms :—

Return or staff bead.
Rebated and beaded boards for partition.
Shouldered or tusk tenon. (11.)

*6. Elevation of a 9-inch arch ring, over an opening in a brick wall built in Flemish bond. Span of arch 6′, and rise 12″.

Draw, to a scale of ¾″ to a foot, showing four courses of the arch bricks at A, and four courses of the wall bricks at B.

*7. Drawing of a stone template to carry the end of a cast-iron girder 10″ deep, with flanges 1¼″ × 8″ and ¾″ × 3″.

Draw the girder, ⅓rd full size, in cross section, showing the template in elevation. (12.)

8. Draw, to a scale of $\frac{1}{48}$, line diagrams showing the difference between a wooden king post and queen post roof truss; one for a span of 36′, and the other for a 24′ span.

Write their names against the different members. (13.)

*9. Section through a portion of a slate roof divided by a party wall.

Draw to a scale of $\frac{1}{12}$, showing the slates, with two different methods of using lead to form a water-tight joint between them and the wall.

The thickness of the slates should be exaggerated, and the section should pass through a lap. (13.)

*10. A is a plan of a roofing slate.

By what name is this sized slate known ?

B is a plan of the ends of 6 common rafters at the eaves of a roof.

Draw B, to a scale of ½″ to a foot, adding 9″ slate boarding, a tilting fillet, and slates, as A, laid to a 4″ lap.

Put 5 slates in width in the doubling eaves course, and one less in each of the 4 following courses.

The nail holes where exposed to show centre nailing. (13.)

11. Draw, to a scale of $\frac{1}{12}$, a vertical cross section through the joint between the kingpost and the tiebeam, the latter being 11″ × 6″, in a timber roof truss.

Show the full details of the stirrup iron, &c., before tightening up. (14.)

*12. Plan of part of a stone stair.

Draw, to a scale of ¾″ to a foot, a section through A—A, showing square steps with rebated joints, a 6″ rise and moulded nosings.

Also a section through B—B. (15.)

*13. Plan of part of a first-floor room in a dwelling-house, the boards being carried on common joists 10″ × 2½″, trimming joists and trimmers 10″ × 3″.

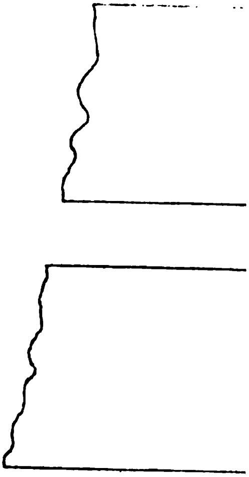
Give, to a scale of ½″ to a foot, a vertical section through A—A, showing a brick trimmer arch and a lath and plaster ceiling below. (16.)

14. Give, to a scale of ⅕, a horizontal section through one jamb of an entrance doorway to a dwelling house, the outer walls being 18″ brickwork with chamfered stone quoins to openings.

The following to be shown :—

Inner face of wall plastered flush with door frame.
Single architrave to door frame.
Hanging style of door 6″ × 2½″.
Panel (part only) bead flush and moulded at back. (16.)

(2



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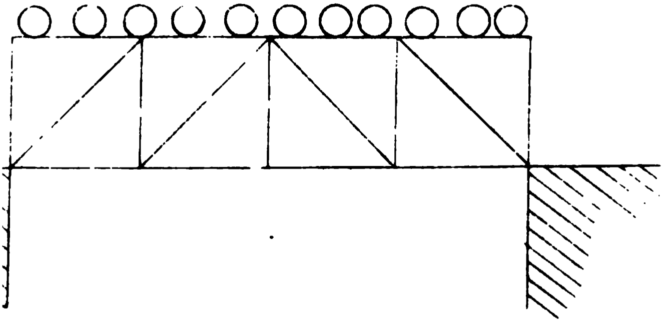

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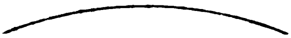

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.
You are only permitted to attempt *six* questions.

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21. Explain the meaning of "hydraulic lime," and how you would practically test a specimen of limestone in order to ascertain whether it would produce an hydraulic lime. (12.)

22. Describe the difference in both the behaviour and appearance of similar bars of cast and wrought iron—
    (*a.*) When broken under a tensile stress suddenly applied.
    (*b.*) When broken under a slowly applied tensile stress. (12.)

*23. Plans of two successive courses at the end of a brick wall built in English bond.
    Draw, to a scale of ¾″ to a foot, showing the use of diagonal bond in both courses, to strengthen the wall. (12.)

*24. Elevation of a beam loaded with 15 tons at a point out of the centre.
    What proportion of the weight is borne at each of the two supports, A, B?
    What portion of the beam is in tension, and which in compression? (14.)

*25. Line diagram of a girder constructed for a uniform load, as shown.
    Draw to twice the size, showing the members in tension by single, those in compression by double, and those under compression and bending stress by triple lines; the stresses due to their own weight to be neglected.
    Draw a similar diagram, supposing the same load to be along the bottom instead of the top of the girder, omitting any bars you consider superfluous, and making any other alterations you think necessary. (14.)

*26. Section of part of a single floor with common joists 9″ × 2½″.
    Draw, to a scale of ⅛, a sectional elevation through AA, showing the five floor battens, and four ordinary methods of forming a tight joint between them. (14.)

27. Draw, to a scale of 1½″ to a foot, a cross section of a double faced moulded skirting, 15″ high, tongued to floor, and secured to wood grounds plugged to a brick wall. (16.)

*28. Line diagram of part of an iron roof truss for a 38 feet span, the rise being ¼ the span, and the camber of tie rod $\frac{1}{30}$ the span.
    Draw a line diagram of the complete truss, to a scale of $\frac{1}{96}$.
    Give an elevation of the joint at A, ½ full size, with any details required to fully explain its construction, *aa* being angle irons 2½″ × 2½″ × ⅜″; and *bb* (not continuous), as well as *c*, to be of 1¼″ round iron. (16.)

*29. Plan of part of the top of a wall at the angle of a building, showing the wallplates to carry a hipped roof.

Draw, to a scale of ¾″ to a foot, adding an angle tie and dragon beam. Give a vertical section through the dragon beam, showing its connexion with the angle tie and the foot of the hip rafter. (16.)

30. Two iron plates 10″ × ½″ are to be connected by a riveted lap joint.

Draw, ¼ full size, a plan of a double riveted joint, the rivets being ¾″, with a pitch of 2⅝″.

Show by another plan a similar joint, but with the rivets arranged so as to weaken the plates as little as possible. (17.)

*31. Elevation of a brick archway.

Draw, to a scale of $\frac{1}{24}$, showing the centering you would use in its construction. Full details to be given, with the scantlings, including supports. (17.)

32. Give a horizontal section, to a scale of 1½″ to a foot, through a cased window frame for 2¼″ double hung sashes; the wall being of stone, 24″ thick, finished inside with lath and plaster on battens, and square boxed shutters for a 4 feet opening. (18.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions.

41. Write out a specification for the Portland cement concrete in the foundations of a building. (8.)

42. What is the drying of paint due to?

What is the object of graining woodwork, and what does the ordinary priming coat consist of?

Is there anything done to woodwork before priming, and, if so, what and why? (8.)

43. A plastered ceiling shortly after completion became blistered all over. What would be the cause of the blistering, and how could it have been guarded against? (8.)

44. What wind force per foot super would overturn a 14″ brick wall, 10′ high and weighing 108 lbs. per foot cube, neglecting the strength of the mortar. (8.)

45. A girder over a 20 feet span, AB, carries at 5′ from A a load of 3 cwts., at the centre a load of 5 cwts., and at 5′ from B a load of 7 cwts.

Give the reactions at A and B, and the shearing stress to which the girder is exposed between the centre and the load of 7 cwts. (8.)

46. Explain how the classic orders of architecture are applied in the Italian styles known as Roman, Florentine, and Venetian. Give sketches to illustrate your meaning. (8.)

47. The front wall of a building is finished with a cornice and brick parapet. The lead gutter in rear of the parapet is 50 feet long, currented from the centre to both ends.

Draw a plan of the gutter, to a scale of 5′ to an inch, and enlarged sections showing the joints in the lead and between the lead and the slates. (10.)

48. Draw, to a scale of 1″ to a foot, a vertical cross section through a semicircular headed window opening 5′ × 2′ 6″, in an 18″ brick wall; showing a gauged arch, double hung sashes, and a panelled window back; the details to be suitable to a good dwelling-house.

Give a full sized section of an ovolo sash-bar for the same. (10.)

49. Give a line diagram of an iron roof truss for a 35 feet span; and make working drawings, half full size, of the joints at the head and foot of the principal rafter, showing the latter resting on the top of a cast-iron column. (10.)

50. Give a section, to a scale of an inch to a foot, with a perspective sketch, showing the bracketing for a coved plastered ceiling, the height being 3 feet and the projection 20″. (10.)

51. Draw, to a scale of 4 feet to an inch, a section through an open wooden roof over a 32 feet span, showing a skylight with open louvres for ventilation.

The roof to rest on 14″ walls and to be finished with cast iron ogee guttering. (10.)

52. A new pair of hinged wooden gates is required for the arched entrance to a warehouse. The entrance is 11′ wide, with square stone piers, 3′ on face, and 10′ high from ground to a plain impost which carries a segmental arch with a 3′ rise.

Give a part elevation of the gates, to a scale of ½″ to a foot, and enlarged details showing their construction. No wicket to be shown; they must be strongly and effectively designed, but need not be the whole height of the opening. (10,)

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E. (Ret.).

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at his own home. The drawings are to be sent by post to the Secretary, Department of Science and Art, London, S.W., on or before the 23rd of June. The postage need not be prepaid.

Draw up a design for a small detached hospital to be built in the country, on the top of some rising ground.

A good thin bedded rubble stone, as also bricks, can readily be obtained in the locality.

The site is on the east of a road running north and south, the plot being rectangular, containing about three acres, with a depth of 300 feet.

The soil is a good firm gravel.

The accommodation required is:—

Ward for 12 beds.
Two wards for 4 beds each.

1,200 cubic feet and 90 feet superficial to be allowed per bed.

Ward scullery about 90 feet superficial.

Accommodation for two nurses, about 90 feet superficial for each, in one or two rooms.

Waiting room, about 90 feet superficial.

Bath-room.

Two w.c.'s and urinals for large ward, and one for the two small wards.

The following to be completely cut off from the hospital proper:—

Kitchen; cook's room; scullery; larder; store for medical comforts; store for clothing, bedding, &c., about 100 feet superficial.

All the work must be sound and good, the rooms conveniently arranged, and all sanitary requirements carefully attended to.

Plans and elevations to be drawn to a scale of 8 feet to an inch, sections to twice the scale of the plans, and enlarged details to be given as may be required. A small site plan to be given, showing positions of any out buildings, such as mortuary and washhouse.

The drawings must be fully dimensioned, and sufficiently complete to allow of accurate bills of quantities being taken out from them, with the exception of out buildings, which need only be shown on the general plan.

The approximate cost of the block, ascertained by cubing out the contents, to be stated, and a short description given of the materials proposed to be employed, and of any points requiring special explanation. A specification is not required.

The following voucher must be signed and returned with the worked drawings:—

I, ____

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Building Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed)__________________________

No.________

The above number must be quoted on each separate sheet of drawings worked by you.

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them. Sketches, required to be made to *scale, must be inked in with drawing pen.*

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *ten* questions.

You must *attempt No.* 21. Two of the remaining questions may be selected from the Calculations; **and the rest from one, but not from both, of the sections of Practical Shipbuilding.**

PRACTICAL SHIPBUILDING.—SECTION I.

WOOD AND COMPOSITE SHIPS.

1. Show by sketches how two pieces of wood keel are usually connected together. (8.)

2. How would you side and mould a *half*-floor? (12.)

3. How are the garboard strakes usually fitted in a wood ship?
What purposes do such strakes serve? (8.)

4. How are the positions of the dowel or coak holes in the heads and heels of the frame timbers set off?
How are the holes bored?
Why is it important that the butts of the frame timbers should be well fayed, and the dowels tightly fitted? (12.)

5. How would you get in place the wood beams of a ship when there is a considerable tumble home in the ship's sides? (8.)

6. What is the *thin* waterway?
Show how the ends of the deck plank are usually scored into the thin waterway, and give the reasons for adopting the arrangement. (8.)

7. Sketch roughly a frame of a composite vessel, and mark on it the names of the different parts. (8.)

8. Show how the intercostal keel in a composite vessel is secured to the frames.
What longitudinal ties usually connect the different pieces of the intercostal keel to each other? (8.)

9. Explain how the work of *framing* a composite vessel is proceeded with on the blocks. (12.)

10. What is a stringer plate?
Show how such a plate is secured to the framing of a composite vessel. (10.)

PRACTICAL SHIPBUILDING.—SECTION II.

IRON AND STEEL SHIPS.

11. Roughly sketch a *pan*-head rivet:—
(1) with a countersunk point;
(2) with a snap point.
State in what parts of a ship's structure each kind is generally used. (8.)

12. Sketch a *side*-bar keel, showing how the butts are arranged. (8.)

13. Explain how the work of erecting the frames on the blocks of a small mercantile iron or steel vessel is proceeded with. (12.)

14. **What is the breadth of lap required by Lloyd's rules for—**
    (1) **single riveting;**
    (2) **double riveting?**

Show how you would space the rivets in a double-riveted lap if it is to be made watertight, and the plates are ⅝" thick. (8.)

15. **Give a sketch of a drift punch. For what purpose is it used?**
When, and why, would it be undesirable to use such a punch? (8.)

16. **How is the bottom plating usually fastened to the stern post in—**
    (1.) **A large armour-clad ship?**
    (2.) **A small mercantile vessel?** (8.)

17. **What are the ordinary methods of forming knees to beams in iron and steel ships?** (8.)

18. **Show how you would fit and fasten a** **beam to the frames of a ship.** (12.)

19. **Describe the work of *riveting* the bottom plates to the frames and to each other.**
How would you ascertain—
    (1.) **That the surfaces of the plates are brought close together.**
    (2.) **That the rivets are tight?** (12.)

20. **What is a stringer plate?**
Show how such a plate is secured to the framing of an iron or a steel ship. (10.)

DRAWING.

21. **Sketch No. 21 is on a scale of ⅛" to 1 foot. Enlarge it to a scale of ¼" to 1 foot, and show on it a station 10' 6" before the after perpendicular, and a water-line 13' 6" above under side of keel.** (14.)

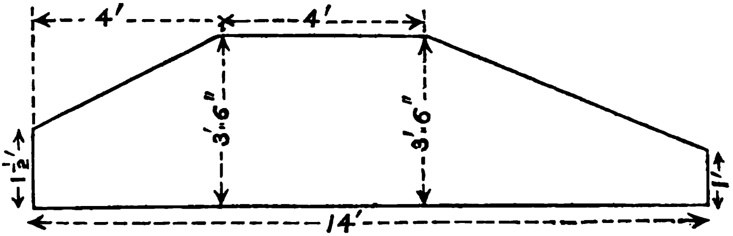
CALCULATIONS.

22. **Write down and explain Simpson's first rule for finding the area of a plane surface.**
The *half*-ordinates of a deck plan in feet are respectively 1¼; 5½; 10¼; 13½; 14¾; 14½; 12½; 9; and 3½; and the length of the plan is 128 feet.
Find the area of the deck plan in square yards. (8.)

23. **Referring to Question No. 22, find the area in square feet of the portion of the plan between the ordinates 1¼ and 5½.** (6.)

24. **The areas of the water-line sections of a vessel in square feet are respectively 2,000; 2,000; 1,600; 1,250; and 300. The common interval between them is 1½ feet. Find the displacement of the vessel in tons, neglecting the small portion below the lowest water section.** (6.)

25. A steel plate $\frac{9}{16}$" thick is of the form and dimensions shown below. Find its weight in lbs.



(6.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *twelve* questions.

You must attempt No. 51. The remaining questions may be selected from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

31. Show how the keel, floors, keelson, and garboard strakes of a wood ship are connected together. (6.)

32. How would you side and mould a *half*-floor? (8.)

33. The frames of a wood ship being in place, explain how the *dubbing out* of the inside of the frames is performed.
What precautionary measures should be taken in proceeding with the work? (6.)

34. The outside plank of a wood vessel being trimmed and ready to go in place; describe the work in connexion with securing it temporarily in place. (6.)

35. How are intercostal keels in composite vessels usually fitted and secured to the frames?
Why are such keels fitted? (6.)

36. Explain how the work of *framing* a composite vessel is proceeded with on the blocks. (8.)

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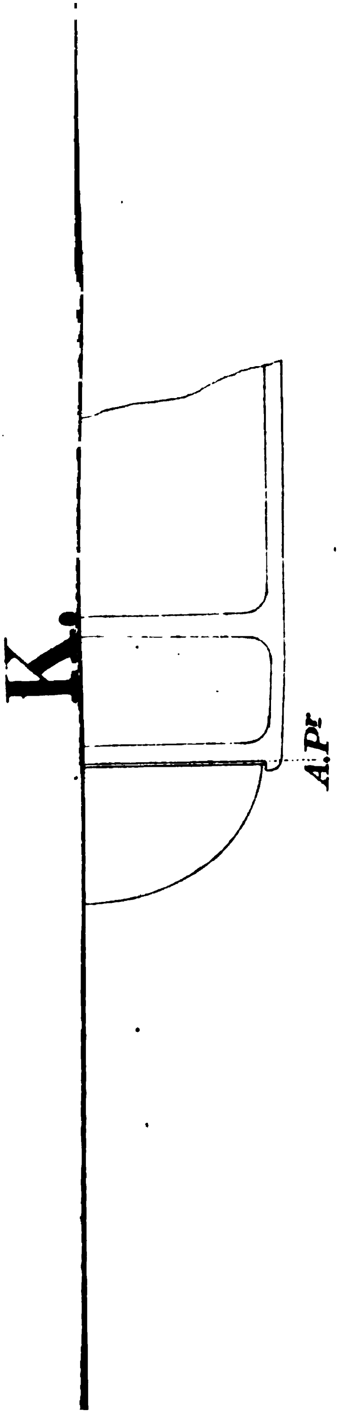

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SUBJECT IV. ADVANCED STAGE.

No. 51.

37. Describe the work of *fastening* the inner thickness of bottom plank in a composite vessel which has two thicknesses of bottom plank. (6.)

IRON AND STEEL SHIPS.

38. Sketch roughly a *bar* keel and a *side-bar* keel, showing how the butts are usually arranged and fastened in each case. (6.)

39. Describe the tests to which Z steels are subjected to ascertain if they are fit for use.

40. How are Z bar frames bevelled and bent to their proper curvature? (8.)

41. The frames, reverse frames, and floor plates of a mercantile steel vessel having been adjusted; explain how the work of riveting them together is proceeded with. (6.)

42. State broadly what are the requirements of Lloyd's Rules as to fitting and securing the outer plating of ships. (6.)

43. Show how you would fit and fasten a T beam to the frames of a ship. (8.)

44. Show how the bottom plating is fitted and fastened to the stern-post of—

    (1) a small mercantile vessel;
    (2) a large armour-clad ship. (8.)

45. In arranging the butt fastenings of a stringer plate, what consideration should be given to the row of rivets farthest from the butt?

    What would influence you in determining the thickness of the strap? (6.)

46. What is meant by—

    (1) local strength;
    (2) structural strength?

    Point out in what ways pillars to beams, if properly fitted, may be regarded as increasing the *structural* strength of iron and steel ships. (8.)

LAYING OFF.

47. Explain clearly a method of obtaining the bevellings of the frame timbers in the square body, and state how the information is communicated to the workmen. (6.)

48. How are the edges of the outer bottom plates obtained and faired on the mould loft floor? (6.)

49. How are the beam-at-side lines obtained, and how are they set off at the ship? (8.)

50. How is a scrive board made, and to what uses is it put? (8.)

DRAWING.

51. Sketch No. 51 is on a scale of ½″ to 1 foot, enlarge it to a scale of 1″ to 1 foot, state what it represents, and show the rivets in the angle bars *a, a, a*. (12.)

CALCULATIONS.

52. The *half*-ordinates in feet of the load water plane of a vessel are respectively:—0·2; 4; 8·3; 11·3; 13·4; 13·4; 10·4; 7·2; and 2·2; the length of the plane being 130 feet.

Find—
(1) the area of the plane;
(2) the distance of its C.G. from No. 5 ordinate;
(3) the decrease in draught of water by removing 25 tons from the vessel. (8.)

53. A ship passes from sea-water to river-water, show how an estimate may be made for the change in the draught of water.

What will be the mean draught in *river*-water of a ship whose mean draught in *sea*-water is 25 feet, her length on the water-line being 320 feet; breadth extreme 48 feet, and displacement 7,500 tons? (6.)

54. The areas of five equi-distant water-planes of a vessel in square feet are respectively—

1—4100
2—3700
3—3200
4—2500
5—1400

the common interval between them is 2 feet, and the displacement below the lowest water-plane is 50 tons.

Find—
(*a*) the tons per inch at each of the water-planes;
(*b*) the displacement in tons up to each of the first four water-planes. (8.)

55. Explain clearly, illustrating your remarks with rough sketches, how *curves of displacement* and *curves of tons per inch immersion* are constructed, and state what use is made of them. (6.)

56. A portion of a cylindrical steel stern shaft tube 1½″ thick, is 15¼ feet long; and its external diameter is 15″. Find its weight. (6.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *fourteen* questions. You may select these from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

71. What is the apron? A piece of apron has great curvature, how would you efficiently connect it by coaks to the stem? (6.)

72. The outside plank of a wood vessel being trimmed and ready to go in place, describe the work in connection with securing it temporarily in place, and the necessary arrangements which should be made for setting off the permanent fastenings in an efficient manner. (8.)

73. Briefly discuss the comparative value of—

treenail fastenings
through bolt fastenings

for outside plank in wood vessels. (6.)

74. Explain why a flat keel plate is usually worked in composite vessels in addition to a wood keel.

Show how the two keels are usually connected and fastened together. (6.)

75. Sketch roughly a portion of the transverse framing extending from the keel to the water line of—

(1) a mercantile composite vessel,
(2) a recent type of a composite vessel of war.

(8.)

IRON AND STEEL SHIPS.

76. What is the difference between a side-bar keel and a flat keel?

Show how the butts are usually arranged and fastened in each case, specifying sizes of plates and rivets. (6.)

77. Explain briefly how the work of erecting the frames of a small mercantile steel vessel is usually proceeded with. (6.)

78. Sketch roughly a portion of a section, and an intermediate section, of the cellular system of framing adopted in many mercantile ships.

How does this system differ in details from that used in armoured ships of war? (8.)

79. What are the advantages in using Z steels for the transverse frames, as compared with frames formed with two angle bars? Are there any disadvantages? (6.)

80. In large steel castings, such as those for stems, stern-posts, &c., what tests are usually applied to ascertain if they are sound and fit for use? (6.)

81. What is the principal object in fitting efficient beam knees?

What may be regarded, in many iron and steel ships, as horizontal knees to each beam; and what useful work do these horizontal knees perform? (6.)

82. Beams in iron and steel ships are generally made of uniform depth throughout, except at their extreme ends. On the principle of uniformity of strength, regarding the beams as girders only, the adoption cf this uniform depth appears to be incorrect.

Discuss fully why the uniform depth is adopted. (8.)

LAYING OFF.

83. Explain briefly how the midship body may be faired by contraction. Show that the method is correct. (6.)

84. Define the "centre of rabbet."

Show how it may be found *exactly* in a ship whose stem rakes and tapers. (8.)

85. How are the edges of the outer bottom plates obtained and faired on the mould loft floor?

Show roughly the general contour of the plate edges in the fore body plan. (6.)

86. How is a scrive board made, and to what uses is it put? (6.)

87. What information should be given to the workmen to enable the iron stem of a large armour-clad ship to be forged and machined? (6.)

CALCULATIONS.

88. The *half*-ordinates of a portion of a deck plan of a vessel, commencing from abaft, are 2; 8; and 11½ feet respectively, and the common interval is 16 feet.

On the beams between the two aftermost ordinates, steel plating ½ inch thick is to be worked. What is the weight of the plating? (4.)

89. From the particulars given below find the displacement in tons of the vessel up to L.W.L.

Half-ordinates in feet at stations:—

	1	2	3	4	5
L.W.L.	·2	7·4	11·0	9·3	2·0
2 W.L.	·2	5·3	10·5	6·5	·3
3 W.L.	·2	2·0	7·6	2·6	·3

Stations apart 30 feet.
Water lines apart 3 feet.
(Appendages before and abaft end ordinates, and below No. 3 W.L. being neglected.) (6.)

90. Describe clearly how you would proceed to obtain from the drawings of a vessel, a close approximation to the area of "wetted surface" for a given draught of water forward and aft. (6.)

91. A pontoon raft is formed by two cylindrical pontoons each 50 feet long and 4 feet in diameter. The distance between the centres of the pontoons is 8 feet throughout their lengths.

In sea-water the raft floats with the axes of the pontoons at the surface of the water.

Find the height of the transverse metacentre above the centre of buoyancy of the raft. (6.)

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is meant by "change of trim"?

is desired that the draught of water *aft* in a steam ship shall nstant whether the coals are in, or out, of the ship.

ow how the approximate position of the C.G. of the coals may ound, in order that the desired condition may be fulfilled. (8.)

fly describe an *experimental* method of obtaining a curve of bility for a ship.

Compare the method with the calculation method. (6.)

w would you proceed in arranging the fastenings in a stringer te at the beams, and at the butts?

A stringer plate is 38 inches wide and $\frac{7}{16}$ inch thick; sketch the veting in a beam, and at a butt, and show that the arrangement a good one. (8.)

how how a comparison may be made between the turning effects n a ship of—

(1) A narrow rudder held at a certain angle by a given force at the end of a tiller; and

(2) A broader rudder of equal depth held by an equal force at a smaller angle. (8.)

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidates at their own homes. The drawings are to be sent by post to the Secretary, Department of Science and Art, London, S.W., on or before the 23rd of June. The postage need not be prepaid.

101. Portions of the sheer and body plans of a steel screw vessel on a scale of $\frac{1}{8}$ inch to 1 foot, with particulars of dimensions, are given on drawing No. 101.

Make a *complete* building draught on a scale of $\frac{1}{4}$ inch to 1 foot, from the information furnished, and:—

(1.) Mark distinctly on the drawing constructed by you the position of the centre of buoyancy when the vessel is floating at a load line of 9′ 6″ forward; 10′ 6″ aft.

(2.) Construct the curve of displacement on a scale of 1 inch per foot of draught, and 1 inch per 100 tons displacement.

(3.) Construct the curve of tons per inch immersion on a scale of 1 inch per foot of draught, and $\frac{1}{4}$ inch per ton.

The following voucher must be signed and returned with the worked drawings:—

I, ______________________________

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Naval Architecture, have been done wholly by me, and without assistance from any person.

(Signed) ______________________________

No. ______

The above number must be quoted on each separate sheet of drawings, &c. worked by you.

SUBJECT V. PURE MATHEMATICS, STAGES 1, 2, & 3.

EXAMINERS, REV. J. F. TWISDEN, M.A., AND
A. R. WILLIS, ESQ., M.A., D.Sc.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You are permitted to answer questions from the First Stage, or from the Second Stage, or from the Third Stage, or from the Honours Paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Every page of the paper supplied for the answers may be used.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

All the work by which a result is obtained must be clearly shown *in immediate connexion with the question.* No credit will be allowed for any result, however correct it may be, unless the work be shown, so as to enable the Examiners to satisfy themselves that the candidate has understood the question, and to see by what process the result has been obtained.

Anything which you do not wish the Examiners to notice should be crossed out with the pen.

A table of logarithms must NOT be used in working these papers. All the logarithms needed will be found on the accompanying paper.

Unless you expressly state the contrary, it will be assumed that you have read GEOMETRY *in Euclid, and you will be expected to follow Euclid's sequence. Otherwise, you must state what text book you have used in geometry.*

The examination in this subject lasts for three and a half hours.

Mathematics, First Stage.

INSTRUCTIONS.

Read the General Instructions above.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

Section A.

1. Reduce to their simplest forms :—

(*a.*) $\frac{2\frac{1}{2}}{5\frac{5}{7}}$ of $1\frac{1}{8} - \frac{15\frac{3}{4} - 4\frac{3}{7} \text{ of } 3\frac{1}{2}}{3\frac{5}{9} \text{ of } \frac{3}{8} + 2\frac{2}{3}}$.

(*b.*) $(0{\cdot}002 \times 36{\cdot}25 \div 0{\cdot}029) - (102{\cdot}85 \times 0{\cdot}04 \div 1{\cdot}7)$. (10.)

2. Extract the square root of 0·571 to four places of decimals, and the cube root of 768575·296. (8.)

3. All round the floor of a room, which is 28 feet long and 22 feet wide, there is a border 2 feet wide which is left uncarpeted. Find the cost of staining the border at 1*s.* 1½*d.* a square yard. Find also the number of yards of carpet, 27 inches wide, required for covering the rest of the floor, and the cost of this carpet at 3*s.* 9*d.* a yard. (10.)

4. What is the rate per cent. of the interest that a man gets on money invested in a 4 per cent. stock, the price of which is 119⅝ (including brokerage)? What income would he get on 1,500*l.* so invested? (8.)

5. A and B are partners in a business in which A has invested 6,750*l.* and B 1,500*l.*; B receives 15 per cent. of all the profits for acting as manager, and the remainder is divided between the partners in proportion to the sums invested; what will each receive out of profits amounting to 726*l.* 9*s.* 2*d.*? (10.)

6. A kilometre being 1093·638 yards, find to four places of decimals how many kilometres there are in 100 English miles. (8.)

Section B.

7. Two angles of a triangle are equal; show that the sides opposite to these angles are equal.

In the equal sides AB, AC of an isosceles triangle ABC points D and E are taken, so that AD is equal to AE, and CD and BE are drawn intersecting in F; show that the triangle BFC is isosceles. (12.)

8. Show how to divide a given angle into two equal parts.

If a diagonal AC of a quadrilateral ABCD bisects the angles at A and C, show that it is at right angles to the other diagonal BD. (10.)

9. If one angle of a triangle is greater than another, show that the side which is opposite the greater angle is longer than the side which is opposite the less angle.

ABC is a triangle having an acute angle at B, which is greater than the angle at A; the side AB is produced to D, and BE is drawn to meet AC produced in E in such a way that the angle DBE is equal to the angle ABC; show that BE is longer than BC. (10.)

10. Show that the complements of the parallelograms which are about the diagonals of any parallelogram are equal to one another.

If one of the parallelograms about the diagonal of any parallelogram is equal to half one of the complements, show that the complement is equal to half the other parallelogram. (12.)

11. ABC is a given triangle and P a given point; show how to draw through P a straight line to cut AB and AC (or those sides either or both produced) in Q and R, so that AQR may be an isosceles triangle.

Within what space must P be situated if Q and R are on the sides (not the sides produced) respectively? (14.)

12. In the triangle ABC the angles at A and C are each one-fourth of a right angle; CD is drawn cutting AB produced at right angles in D; show that the square on AB is double the square on BD. (14.)

Section C.

13. If $x = 3$ and $4y = -1$, find the numerical values of the following expressions:—

$$4(x-4y^3),\ (x-2y)\,(x+3y),\ \frac{x-\frac{2}{y}}{x+\frac{2}{y}},\ x^3y^5. \qquad (12.)$$

14. Write down the following expressions in factors:—

x^2-x-2, $x^4+4x^2y^2+16y^4$, $x^2-y^2-6x+6y$. (10.)

15. Subtract $(x^2-7x+13)^2$ from $(x^2+7x-13)^2$. (10.)

16. Reduce the following expressions to their simplest form:—

(*a.*) $\dfrac{1}{x-1}-\dfrac{x}{x^2+x+1}$.

(*b.*) $\dfrac{\frac{c}{a}}{\left(1-\frac{b}{a}\right)\left(1-\frac{a}{c}\right)}-\dfrac{\frac{a}{c}}{\left(\frac{b}{a}-1\right)\left(\frac{a}{c}-1\right)}$.

(*c.*) $\left(1-\dfrac{x+1}{x^2-4x+5}\right)\left(1-\dfrac{2x-4}{x^2-2x+1}\right)$. (14.)

17. Find a number such that, when diminished by 3, one-fourth of the remainder may be greater by 2 than one-fifth of the original number. (12.)

18. A person spent 9*s.* in buying apples at the rate of 7*d.* a dozen, and oranges at the rate of 20 a shilling. If he had bought two-thirds as many apples and twice as many oranges, he would have had to pay 13*s.* 4*d.* How many of each did he buy? (14.)

Mathematics, Second Stage.

INSTRUCTIONS.

Read the General Instructions on p. 30.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

Section A.

21. Simplify $\dfrac{x^2-8x+12}{3x^2-17x-6}-\dfrac{2x^2+5x+2}{6x^2+x-1}$, and find its value when $3x=\sqrt{2}-1$. (15.)

22. Find the square roots of the following expressions:—

(*a.*) $(x-y)^4-2(x^2+y^2)(x-y)^2+2(x^4+y^4)$.

(*b.*) $a^2+2abx+(b^2-4ac)x^2-4bcx^3+4c^2x^4$. (25.)

23. Which is greater $\sqrt{3}$ or $\sqrt[3]{(5\frac{1}{5})}$?

Find in its simplest form the product of $\sqrt{6}-\sqrt{2}$ and $\sqrt{2}+\sqrt{3}+\sqrt{\frac{2}{3}}$. (15.)

24. If a and b are the roots of the equation $x^2+px+q=0$, show that $a+b=-p$, and $ab=q$; and show that the equation whose roots are $a+\frac{1}{b}$ and $b+\frac{1}{a}$ may be expressed in the form—

$$qx^2+p(1+q)x+(1+q)^2=0. \qquad (25.)$$

25. Define the triplicate ratio of $a : b$.

Find the number that must be subtracted from the antecedent and consequent of the ratio 3 : 5 so that the resulting ratio may equal the triplicate ratio of 4 : 5. (20.)

26. One side of a rectangle is 3 feet longer than the adjacent side; the area is as many square feet as the number of linear feet in the perimeter; find the sides of the rectangle. (20.)

Section B.

27. Show that if a straight line be divided into any two parts, the squares on the whole line and on one of the parts are equal to twice the rectangle contained by the whole line and that part together with the square on the other part.

Let ABC be a triangle having a right angle at C; from D, any point in AC, draw DE at right angles to AB; without using any property of the circle, show that the rectangle CA.AD is equal to the rectangle BA.AE. (25.)

28. AB is a chord of a circle; C the middle point of AB; show that the straight line drawn through C perpendicular to AB passes through the centre of the circle.

Show that all circles whose centres lie on a given straight line and whose circumferences pass through a given point have a common chord of intersection. (20.)

29. Define similar segments of a circle, and show that on the same straight line and on the same side of it there cannot be two similar segments of circles not coinciding with each other.

A straight line is drawn through the point of contact of two circles touching each other internally; show that the segments cut off on the same side of the line are similar. (20.)

30. Show that in equal circles the arcs which subtend equal angles, whether at the centre or circumference, are equal.

ABCD is a quadrilateral inscribed in a circle whose centre is O; if the angles BAD and BOD are together equal to two right angles, show that the arc BAD is double the arc BCD. (25.)

31. Show that a tangent to a circle makes with a chord through the point of contact angles equal to those in the alternate segments of the circle.

In the hypothenuse AB of a right-angled triangle ABC a point E is taken, so that AE equals AC; CD is drawn to meet AB at right angles in D; show that the line joining C and E bisects the angle BCD. (25.)

32. Given a circle and two parallel chords, show how to draw a circle to touch both chords, and the circle internally. (25.)

Section C.

33. Define the mantissa of a logarithm, and the base of a system of logarithms. Point out the advantage gained by taking 10 as the base of the common system of logarithms.

Show that $\log \frac{a}{b} = \log a - \log b$, and find the fifth root of $(0{\cdot}0002 \div 23087)$. (20.)

34. Find the sine, cosine, and tangent of an angle of 60°, and write down the sine, cosine, and tangent of an angle of 120°. Given that $2 \tan 26° 34' = 1$, write down all the values of θ less than four right angles for which $2 \tan \theta + 1 = 0$. (20.)

35. Find the logarithm of the tangent of 81° 11′ 45″, and the angle whose log cotangent is 9·6170456.

Find the numerical value of $\sqrt[3]{}\,(\tan 50° \tan 22° 30')$. (20.)

36. If two sides a, b and the angle A of the triangle ABC are given, under what circumstances will there be two values for the third side? Show that the difference of these values is

$$2\sqrt{(a^2 - b^2 \sin^2 A)}.$$

Find the smaller value of c, having given $A = 10°$, $a = 2308{\cdot}7$, $b = 7903{\cdot}2$. (25.)

37. Prove geometrically that the sum of two sides of a triangle is to their difference as the tangent of half the sum of the opposite angles is to the tangent of half their difference.

In a triangle ABC, given $a = 3$, $b = 5$, and $C = 120°$, find the tangent of $(B - A) \div 2$. (25.)

38. AB is a vertical pole 50 ft. high, A being above B; BC s inclined upward at an angle of 20° to the horizontal line BD, so that ABC is an angle of 70°; the shadow of AB on BC is 50 feet long; if the shadow fell on BD what would be its length? (25.)

Mathematics, Third Stage.

INSTRUCTIONS.

Read the General Instructions on p. 30.

You must confine your answers entirely to Sections A and B, or to Sections A and C; and you must not answer more than *four* questions in either section.

You must not answer more than eight questions altogether.

The number of marks assigned to each question is given in brackets.

Section A.

41. Find the values of a and b for which the expression

$$\frac{a\sqrt{(n+1)}}{\sqrt{(n)}+\sqrt{(n-1)}} + \frac{2b\sqrt{(n)}}{\sqrt{(n-1)}+\sqrt{(n+1)}} + \frac{\sqrt{(n-1)}}{\sqrt{(n+1)}+\sqrt{(n)}}$$

equals zero. (35.)

42. Solve the equations :—

$$x^2+2yz=y^2+2xz=\frac{5}{3}, \qquad z^2+2xy=\frac{17}{3}. \qquad (35.)$$

43. Explain why the number of permutations of n different things taken two and two together is $n(n-1)$.

How many different permutations can be made of two a's and p other different letters taken two and two together? (35.)

44. Write down and simplify the first four terms and the $(r+1)$th term of the expansion of $(1-4x)^{-\frac{1}{2}}$; find also the middle term of $\left(x-\frac{1}{x}\right)^{2n}$. (35.)

45. A line of given length moves between two lines at right angles to each other, having one of its ends on each of them; find when its centre is at a minimum distance from a given line. (40.)

46. A, B, C are three points on the circumference of a circle; D is the middle point of the arc AB and E is the middle point of the arc BC; draw the chord CE; join AE and CD intersecting in F; show that CE is equal to EF. (40.)

Section B.

47. Find geometrically sin 18° and sin 54° in a surd form, and show that they are the roots of the equation—

$$4x^2-2x\sqrt{5}+1=0. \qquad (30.)$$

48. If the vertex, A, of a triangle ABC is joined to any point, D, of the base, show that—

$$BC \cot ADC = DC \cot B - BD \cot C. \qquad (35.)$$

49. If a triangle ABC is divided into two right-angled triangles by a line drawn from A at right angles to BC, show that twice the difference of the areas of the right-angled triangles is $bc \sin (B-C)$, and hence show that—

$$b^2 \sin 2C - c^2 \sin 2B = 2bc \sin (B-C). \qquad (35.)$$

50. A and B are two stations 1,000 feet apart; P and Q are two stations in the same plane as AB, and on the same side of it; the angles PAB, PBA, QAB, and QBA are 75°, 30°, 45°, and 90° respectively; find how far P is from Q, and how far each of them is from A and from B. (35.)

51. Find an expression for the area of a regular polygon of n sides inscribed in a given circle.

Six equal circles, of radius a, are placed so that each touches two others, their centres being all on the circumference of a circle; find the area which they enclose. (40.)

52. Find the radius of the circle inscribed in a given triangle.

If r is the radius of the circle inscribed in the triangle ABC, and α, β, γ, the distances of the angular points from the centre of the circle, show that $\alpha\beta\gamma s = abcr$. (40.)

Section C.

53. Show that the angle, subtended at the centre of a sphere by the arc of a great circle joining the poles of two great circles, is equal to the angle of inclination of the planes of the circles.

Let ABC be a spherical triangle with a right angle at C; produce BA to D, making BD a quadrant; and CA to E, making CE a quadrant; join DE; find geometrically the sides and angles of ADE. (40.)

54. Investigate the formula expressing the cosine of an angle of a spherical triangle ABC in terms of the sines and cosines of the sides. If $b+c=\pi$, show that the arc of a great circle drawn from A to the middle point of BC is a quadrant. (35.)

55. ABC is a spherical triangle in which C is a right-angle; show that $\cos c = \text{cotan } A \text{ cotan } B$.

Given $A = 115°$, $B = 45°$; find c. (30.)

56. ABC is a spherical triangle in which C is a right angle: if δ is the arc of a great circle drawn from C to meet AB at right angles, show that—

(*a.*) $\sin^2\delta \sin^2 c = \sin^2 a + \sin^2 b - \sin^2 c$.

(*b.*) $\cos^2\delta = \cos^2 A + \cos^2 B$. (40.)

57. Express the sine, cosine, and tangent of half a side of a spherical triangle, as functions of the angles.

Given $A=90°$, $B=120°$, $C=135°$; find $\sin\frac{a}{2}$. (30.)

58. In the spherical triangle ABC, having given $a=100°$, $B=80°$, $C=120°$; find b and c by aid of Napier's analogies. (35.)

Honours Examination.

Instructions.

Read the General Instructions on p. 30.

You may not answer more than ten questions.

The same value is attached to each question.

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61. If the square root of $a+2\sqrt{b}+2\sqrt{c}+2\sqrt{d}$ can be extracted in the form $\sqrt{x}+\sqrt{y}+\sqrt{z}$, show that—

$$a^2bcd=(bc+cd+db)^2.$$

62. Show that the sum of the infinite series—

$$1+(1+n)x+\left(1+n+\frac{n(n+1)}{\underline{|2}}\right)x^2+\left(1+n+\frac{n(n+1)}{\underline{|2}}+\frac{n(n+1)(n+2)}{\underline{|3}}\right)x^3+\ \ldots\ .$$

is equal to $(1-x)^{-(n+1)}$.

Show that the sum of the first n coefficients in the expansion $(1+x)^n(1-x)^{-2}$ in ascending powers of x is $n(n+3).2^{n-3}$.

63. Resolve the following into their partial fractions:—

$$(a.)\ \frac{1}{(x-1)^2(x^2+4)}. \qquad (b.)\ \frac{x^2}{(x-1)^2(x^2+4)}.$$

64. If n be a prime number, and m any number prime to n, show that $m^{n-1}-1$ is divisible by n.

If m and n be both prime numbers, show that $m^{n-1}+n^{m-1}$ when divided by mn leaves a remainder 1.

65. Find (*a*) in a surd form, (*b*) in a decimal form the coefficient of x^3 in the expansion of $(x+\sqrt{2})^{1+\sqrt{2}}$ in ascending powers of x.

66. A line AB is divided in C so that CB is double AC, and circles are described on AC and CB as diameters; show how to draw through A a line such that the chords intercepted by the two circles may be equal.

67. Show how to describe the greatest equilateral triangle, each side of which passes through a vertex of a given triangle.

68. Through C the middle point of the arc ACB of a given circle, any chord CD is drawn cutting the straight line AB in E; find the locus of the centre of the circle passing through B, D and E.

69. Let O be the centre of the circle circumscribing a triangle ABC; let CO make angles θ and ϕ with the sides CA and CB; show that—

$$c^2 \cos\theta \cos\phi = ab \sin^2 C.$$

70. Find the values of θ which satisfy the equation $\sin 5\theta = \sin\theta$.

Find the limits within which the values of θ must lie, which make $\sin 3\theta$ negative.

71. Find in terms of the given angles, α and β, the values of θ which satisfy the equations:—

$$\cos\theta = \cos\alpha \sec\phi + \sin\beta \tan\phi.$$
$$\sin\theta = \sin\alpha \sec\phi + \cos\beta \tan\phi.$$

72. Show that in any plane triangle—

$$(s-a)^2 \sin A + (s-b)^2 \sin B + (s-c)^2 \sin C = 2S\left(\sin^2\frac{A}{2} + \sin^2\frac{B}{2} + \sin^2\frac{C}{2}\right),$$

where S denotes the area of the triangle.

73. Assuming the resolution of $x^{2n} - 2x^n \cos\alpha + 1$ into quadratic factors, show that—

$$(a.)\ 2\sin\theta = \pm 2^n \sin\frac{\theta}{n}.\ \sin\frac{\pi+\theta}{n} \sin\frac{2\pi+\theta}{n} \ldots \sin\frac{(n-1)\pi+\theta}{n}.$$

$$(b.)\ \sin\theta = \theta\left(1-\frac{\theta^2}{\pi^2}\right)\left(1-\frac{\theta^2}{2^2\pi^2}\right)\left(1-\frac{\theta^2}{3^2\pi^2}\right)\ldots$$

74. If $\tan^{-1}(\cos\theta + \sqrt{(-1)}\,.\sin\theta) = x + \sqrt{(-1)}\,.\,y$, where the letters denote real quantities, find x and y in terms of θ.

75. Show that the arcs of great circles joining the middle points of the sides of a spherical triangle meet the opposite sides in points which lie on a great circle; and if a great circle be drawn through each angle perpendicular to the arc which bisects the sides containing that angle, show that these circles have a common diameter.

76. If A, B, C is a spherical triangle whose angles are together equal to four right angles, show that—

$$\tan\frac{a}{2}\tan\frac{b}{2}\tan\frac{c}{2} = \sqrt{(-\sec A\sec B\sec C)},$$

and show from geometrical considerations that the right-hand side of the equation is real.

TABLES REQUIRED.

Angle.		Log. Sin.
°	′	
10		9·239 6702
20		9·534 0517
26	28	9·649 0203
	29	2740
27	47	9·668 5064
	48	7461
30	31	9·705 6833
	32	8975
36	28	9·774 0459
	29	2168
46	28	9·860 3223
	29	4423
70		9·972 9858
80		9·993 3515

Angle.		Log. Tan.
°	′	
22	29	9·616 8669
	30	7 2243
25		9·668 6725
50		10·076 1865
55		10·154 7732
81	11	10·809 3713
81	12	10·810 2061

Number.	Logarithm.
2	301 0300
23087	363 3675
8	3863
24408	387 5522
9	5500
59266	772 8056
7	8129
71407	853 7408
8	7469
79032	897 8030
3	8085
96396	984 0590
7	0635

$\sqrt{2} = 1\cdot4142136.$

SUBJECT V. PURE MATHEMATICS, STAGES 4 & 5.

EXAMINER, T. P. WRIGLEY, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Fourth Stage, or from the Fifth Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The figures in descriptive geometry should not only be constructed with ruler and compasses, but the construction should in all cases be explained and its accuracy demonstrated.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Fourth Stage.—Subjects: Plane, Solid, and Descriptive Geometry and Geometrical Conics.

INSTRUCTIONS.

You are not permitted to attempt more than *eight* questions, and may select them from any part of the paper.
The values attached to the questions are shown in brackets.

1. Give the necessary and sufficient conditions that two triangles may be similar: also that two polygons may be similar.
   Show that the areas of similar triangles are as the squares on corresponding sides.
   A triangle and a parallelogram have a common angle, and the area of the triangle is three times that of the parallelogram; give the relation connecting those sides of the two figures which contain the common angle. (18.)

2. Show how to trisect the arc of a circle whose chord is the side of a regular pentagon inscribed in the circle.
   If regular figures of five, six, and ten sides respectively be inscribed in the same circle, show that the square on a side of the hexagon and the square on a side of the decagon are together equal to the square on a side of the pentagon. (18.)

3. If four parallel lines are given in position, show that they cut off on any transverse line segments which are in a constant ratio.

Similar and similarly situated polygons are described on AB and CD, which are given unequal parallel lines. Show that all the lines joining corresponding corners meet at a point. (16.)

4. If two lines which intersect are respectively parallel to two other intersecting lines, show that the plane of the former pair is parallel to the plane of the latter pair, or coincident with it.

A pyramid on a four-sided base is cut by any number of parallel planes; show that the sections are similar figures, and that the points of intersection of the diagonals of all the sections are in a straight line. (18.)

5. PABCD is a pyramid whose base ABCD is a square. QEFG is another pyramid whose base EFG is an equilateral triangle. AB is equal to EF, and each edge terminated in P or in Q is double AB. Compare the volumes, and also the surfaces of these pyramids, and find the radii of their circumscribing spheres. (20.)

6. Having given a sphere of radius a, find the volume of a segment thereof, whose height is h.

A hollow inverted cone, whose vertical angle is 60° and height 7 inches, is filled with water. Find the volume of water displaced by immersing a sphere of radius 3 inches, until it rests in contact with the cone. Find also the surface of the cone which will remain under water when the sphere is withdrawn. (20.)

7. Define the projections of a point, and the traces of a plane. Having given a plane whose traces are both oblique to the axis, and the vertical projection of a point situated on the plane, find the horizontal projection of the point. Find also the position the point will occupy when the plane is rabatted round its horizontal trace so as to coincide with the horizontal plane. (16.)

8. Having given the projections of a line and the traces of a plane which cuts it, find the projections of the point of intersection. Find also the angles which the line makes with the horizontal plane and with the given plane respectively. (18.)

9. Having given the three plane angles of a trihedral solid angle, show how to construct in the plane of the paper an angle equal to the dihedral angle between any two of the faces of the solid angle. (18.)

10. Show that tangents drawn to a parabola at the extremities of a series of parallel chords intersect on the diameter of the chords.

Find three points P, Q, R, on a given parabola, such that the triangle PQR may have its sides parallel to three given straight lines. (20.)

11. Define an ellipse, and show from your definition that a circle is a particular case of an ellipse.

Show that the feet of perpendiculars from the foci of an ellipse upon all tangents to the curve are equidistant from the centre of the ellipse.

Two ellipses have a common centre; their major axes are inclined at an angle α, and the lengths of their axes are 4, 3, and 4, 2, respectively. Show how to draw their common tangents. (18.)

12. If tangents be drawn from a point P to any conic section whose focus is S, and if Q, Q′ be the points of contact; show that PQ, PQ′ subtend equal angles at S.

If PQRT be a given quadrilateral, and S a focus of the ellipse inscribed therein, show that the sum of the angles STR and SRT is equal to the angle PSQ. (18.)

Fifth Stage.—Subjects: Descriptive Geometry, Spherical Trigonometry, Co-ordinate Geometry of two and of three dimensions.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage paper.

You are not permitted to attempt more than *eight* questions, and may select them from any part of the paper.

The marks assigned to the questions are shown in brackets.

21. The radius of a sphere and the projections of its centre being given, also the projections of a line which intersects the sphere; find the projections of the points of intersection, and the actual distance between them. (35.)

22. Having given the projections of the base and of one of the generating lines of a cylinder, and also those of a line AB which is not parallel to the axis of the cylinder, find the traces of those tangent planes to the cylinder which are parallel to AB.

Within what limits must the angle between AB and the vertical plane lie, in order that the problem may admit of solution? (35.)

23. Define supplemental triangles, and point out how they may be used to establish relations between the sides and angles of a spherical triangle. What limitations are there to the magnitudes of the parts of a spherical triangle? If each of the sides of a spherical triangle be $\frac{\pi}{4}$, find the angles. (30.)

24. If ABP, ABQ, be two spherical triangles of the same perimeter, and D be the middle point of the common side, show that—

$$\frac{\cos DP}{\cos DQ} = \frac{\cos\frac{AP - BP}{2}}{\cos\frac{AQ - BQ}{2}}.$$

(35.)

25. Establish the formula—

$$\tan\frac{A}{2} = \sqrt{\frac{\sin(s-b)\sin(s-c)}{\sin s\,.\,\sin(s-a)}},$$

in the case of a spherical triangle ABC.

Two fixed great circles intersect in A, and are cut in P and Q by a third great circle whose position is variable.

Show that if the sum of the sides of the spherical triangle APQ be kept constant, the circle PQ always touches two fixed small circles. (40.)

26. Establish the formula for the length of the perpendicular drawn from a given point (h, k) upon a given straight line, $\frac{x}{a} + \frac{y}{b} = 1$.

If a straight line move so that the sum of the perpendiculars let fall upon it from two fixed points (3, 4), (7, 2) is equal to three times the perpendicular from a third fixed point (1, 3); show that there is another fixed point through which this line always passes, and find its co-ordinates. (35.)

27. Given the circle whose equation is

$$x^2 + y^2 - \tfrac{1}{2}x + \tfrac{1}{2}y - 5 = 0\,;$$

find the equation of the circle which passes through the points (1, 1) (2, — 1,) (3, 2), also the equation of its common tangents with the given circle, and the length of the common chord. (35.)

28. Obtain the equation of the normal at a given point of the parabola $y^2 = 4ax$; and find the lengths of the normals drawn from the point on the axis distant $8a$ from the focus. (35.)

29. Define the asymptotes of a hyperbola.

If the centre of the hyperbola, whose excentricity is 2, is at the focus of the parabola $y^2 = 4ax$, and if one of the foci of the hyperbola is at the vertex of the parabola, find the equation of the asymptotes.

Find also the area of the quadrilateral, PP′QQ′ determined by the points of intersection of the asymptotes with the parabola. (40.)

30. Show that $3x - 2y + z = 2$ denotes a plane, and indicate by a diagram the position of the plane.

A line passes through the point (1, 2, 1), and is inclined 30° to this plane; find the length of the segment between the given point and the point of intersection with the plane, and also the locus of the point of intersection. (35.)

31. Find the equation connecting the direction cosines of a straight line.

The square ABCD is the base of a regular pyramid, whose vertex is V, and whose height is double AB. V′ is the vertex of a regular tetrahedron whose base ABE lies within the square. Find the distance VV′, and the cosine of the angle VAV′. (40.)

32. Find the condition that the equations

$$\begin{aligned} Ax + By + Cz + D &= 0 \\ A'x + B'y + C'z + D' &= 0 \end{aligned}$$

may represent two planes at right angles.

Find also the equation of the line passing through the point (3, 1, —2) which cuts $4x + y - z = 7$ at right angles. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage paper.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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41. If PQRS be a quadrilateral inscribed in a conic, prove that the intersections of opposite sides and the intersections of tangents at opposite angular points are collinear. What is the pole of the straight line containing the points of intersection? (60.)

42. The axes of two right circular cylinders which intersect each other meet at right angles; show that if the cylinders be developed, the equation of the curve of section on the plane of development is of the form

$$2x^2 - b^2 \cos \frac{2y}{b} = 2a^2 - b^2. \qquad (65.)$$

43. Investigate the harmonic properties of a complete quadrilateral.
Show that the middle points of the three diagonals of a complete quadrilateral lie on a straight line. (55.)

44. What is the condition that the general equation of the second degree in trilinear co-ordinates may represent a circle?
Show that the equation to the circle which passes through the centres of the three escribed circles of the fundamental triangle is

$$a\beta\gamma + b\gamma\alpha + c\alpha\beta + (\alpha + \beta + \gamma)(a\alpha + b\beta + c\gamma) = 0.$$

(65.)

45. Show that in the hyperboloid whose equation is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1,$$

there are two systems of generating lines, and that the perpendiculars let fall from the origin upon these generating lines all lie upon the cone,

$$\frac{a^2}{x^2}(b^2 + c^2)^2 + \frac{b^2}{y^2}(c^2 + a^2)^2 - \frac{c^2}{z^2}(a^2 - b^2)^2 = 0.$$

(65.)

46. Having given the traces of a plane which cuts the axis and both planes of projection obliquely; also the distances from the plane of three points on the same side of it; find the projections of the centre of the sphere which passes through these points and touches the given plane. (60.)

47. Show that it is possible to describe three quadrics, concentric and concyclic with a given quadric, so as to touch a given plane.

(60.)

48. Show that if a curve of the third degree have three real points of inflection, they must lie on a straight line. (60.)

49. Show that all central planes which touch an anchor-ring, cut the surface in two circles.

A surface is generated by the revolution of an ellipse about an axis in its own plane; find the curves in which any double tangent plane cuts the surface. (65.)

50. If the sides of a spherical triangle be small compared with the radius of the sphere, prove that each angle of the spherical triangle exceeds by one-third of the spherical excess the corresponding angle of the plane triangle, the sides of which are of the same length as the arcs of the spherical triangle. (50.)

SUBJECT V. PURE MATHEMATICS, STAGES 6 & 7.

EXAMINER, P. T. WRIGLEY, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Sixth Stage, or from the Seventh Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Sixth Stage.—Subjects: Differential Calculus and Integral Calculus.

INSTRUCTIONS.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

1. Define a differential coefficient. If x denote the population of a country, and y the number of years that have elapsed since a fixed date, what is the meaning of $\frac{dx}{dy}$, and $\frac{d^2x}{dy^2}$ respectively?

Obtain the differential coefficients of the following expressions:—

$$\sqrt{\frac{2-x}{2+x}}, \qquad a^{2x}\log(1-x^2), \qquad \sec^{-1}\left(\frac{a-x}{a-2x}\right),$$

and $(\sin x \,.\, \cos x \,.\, \cos 2x \,.\, \cos 4x)$. (35.)

2. Find the nth differential coefficient with respect to x of the following expressions:—

(α) $a^x \cos 3x$, (β) $a^x \cos x \cos 2x$. (30.)

3. Establish Maclaurin's theorem, and apply it to find the expansion of $\log(2-x)$ in a series of ascending powers of x. Show under what circumstances the series is convergent. (30.)

4. Obtain the equation of the tangent at a given point (x', y') of a curve whose equation is $f(x, y) = 0$.

Write down the equation of the tangent to the curve $xy^2 = a^2(2a-x)$ at the point where it is met by the line $x-y=0$. (30.)

5. Establish a rule for testing whether, when x has a particular value, a given function of x has a minimum value.

The lengths of the sides of a triangle are 4, 5, and 6 units respectively; find the shortest line which will bisect the triangle. (35.)

6. Explain a general method for finding all the rectilinear asymptotes of a given curve. Apply it to discover the asymptotes of the curve

$$x^3(y-2a)+x^2(y^2-3a^2)-ay+ax=0. \qquad (35.)$$

7. How may we obtain a measure of the curvature at a given point of a curve?

Find the equation of the circle of curvature at the point $x=a\sqrt{3}$, $y=a$ of the curve

$$(x+y-a)^2=2ay+a^2. \qquad (40.)$$

8. Explain the method of substituting a new variable in the process of integration: what alteration must be made in the limits of the integral?

Integrate the following integrals:

$$\int \frac{(2+x)dx}{\sqrt{1+x-x^2}}, \qquad \int \frac{dx}{x^2\sqrt{2+x^2}}, \qquad \int_2^4 \frac{dx}{x\sqrt{x^2-3}}.$$

(35.)

9. Show that any rational fraction whose denominator admits of resolution into real factors of the first or second degree can be broken up into a series of fractions which can be separately integrated.

Find the integral of $\frac{(2x^3-x-2)dx}{(x^2+2)(x^2-3x+2)}$. (30.)

10. Obtain the following definite integrals:—

$$\int_0^{\frac{1}{2}} x^2 \sin^{-1}x dx, \qquad \int_0^{\frac{\pi}{4}} \frac{d\theta}{\cos^5\theta}, \qquad \int_0^a x^3(x^2+a^2)^{\frac{n}{2}}dx.$$

(40.)

11. Find the area included between the curve $\frac{y^2}{c^2}=\frac{2cx}{2y^2+3c^2}$, and the straight line $11y-8x+9c=0$. Find also the length of the curvilinear portion of the perimeter of this area. (45.)

12. Having given an ellipse, whose excentricity is $\frac{1}{2}$, and a circle of equal area, which touches the ellipse, at one extremity of the major axis; compare the surfaces of the solids generated by the revolution of these curves about the tangent at their common point. (35.)

Seventh Stage.—Subjects: Differential Calculus, Integral Calculus, Differential Equations, and Finite Differences.

INSTRUCTIONS.

Read the General Instructions at the head of the Sixth Stage paper.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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21. Define partial differentiation, and illustrate by a geometrical example.

Explain its application to the elimination of arbitrary functions; and if $u=\phi(x+ay)+f(x-ay)$, find a relation between the variables and constants which does not involve the arbitrary functions ϕ and f. (40.)

22. Find the equations of the tangent line, the osculating plane, and the principal normal at the point (x', y', z') of the helix, given by the equations $x=a\cos\theta$, $y=a\sin\theta$, $z=b\theta$. (45.)

23. Find the locus of a point which moves so that the area of the triangle formed by the tangent, the normal, and the line through the pole at right angles to the radius vector is constant. (45.)

24. Find the volume contained between the cylinders $z^2=ay$ and $y^2=bx$ and the planes $x=b$ and $z=0$. (50.)

25. Find the value of the integral

$$\iiint\frac{dxdydz}{\sqrt{1-x^2-y^2-z^2}},$$

the integration extending to all points within the sphere $x^2+y^2+z^2=1$. (55.)

26. Establish a rule for finding integrating factors for homogeneous linear equations of the first order and first degree.

Integrate the equations:

$$(\alpha.)\ \frac{dy}{dx}=\frac{3x-2y}{2x-7y},$$

$$(\beta.)\ (1-x^2)\frac{dy}{dx}+2xy-ax^2=0. \qquad (45.)$$

27. What is a singular solution of a differential equation? Show how it is related to the general primitive, and give a geometrical illustration.

Solve the following equations:—

$$\frac{dy}{dx}\{a^2+x^2+x\sqrt{a^2+x^2}\}=a^2-y\{\sqrt{a^2+x^2+x}\}$$

$$x^2\left.\overline{\frac{dy}{dx}}\right|^2-2(xy-1)\frac{dy}{dx}+y^2=0. \qquad (55.)$$

28. Show how to integrate the general linear differential equation with constant coefficients.

Integrate the following equations:—

$$\frac{d^4y}{dx^4}-4\frac{d^2y}{dx^2}-12y=0.$$

$$\frac{d^3y}{dx^3}-a^3y=\cos bx+e^{cx}. \qquad (50.)$$

29. Solve the partial differential equations:—

$$y\frac{dz}{dx}+x\frac{dz}{dy}=x^2-y^2$$

$$\frac{dx}{e^3-5x-y}=\frac{dy}{e^{2z}+x-3y}=dz. \qquad (50.)$$

30. Show that the *m*th differences of a rational integral function of the *n*th degree are of the $(n-m)$th degree if m be less than n, and vanish if m be greater than n.

If $x(x-1)(x-2)\ .\ .\ .\ (x-n+1)\equiv x^{(n)}$, find $\Delta^m x^{(n)}$.

Find also the values of $\Delta^n\left(\frac{x-1}{x^2+3x+2}\right)$, and $\Delta^n\cos^3(ax+b)$.

(50.)

31. If u_x be function of x, show that

$$u_{x+n}=u_x+n\Delta u_x+\frac{n\,.\,(n-1)}{1\,.\,2}\Delta^2 u_x+\,.\,.\,.\,.$$

Find a rational integral function of x which assumes the values 37, 11, 13, 29, when x is equal to 2, 1, -1, -2, respectively. (45.)

32. Apply the calculus of finite differences to obtain the sum of n terms of each of the following series:

(α) $1^4-3^4+5^4-7^4+\dots$

(β) $\frac{1}{\sin\theta\cos 2\theta}-\frac{1}{\cos 2\theta\sin 3\theta}+\frac{1}{\sin 3\theta\cos 4\theta}-\,.\,.\,.\,.$ (45.)

Honours Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions differ but little from one another.

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41. Show how to expand a given function $f(x)$ in a series of ascending powers of another given function $\phi(x)$.

Prove that

$$e^{ax}=1+axe^{bx}+a\,(a-2b)\frac{x^2}{1\,.\,2}e^{2bx}$$
$$+\,a\,(a-3b)^2\frac{x^3}{1\,.\,2\,.\,3}e^{3bx}$$
$$+\,.\,.\,.\,.$$

42. Obtain the values of the following definite integrals:—

$$\int_0^\infty x^{2n}e^{-ax^2}dx, \qquad \int_0^\infty e^{-mx}\cos^{2n} x\,dx.$$

43. Find the differential equation of a curve in which the length of an arc measured from a fixed point is a given function of the abscissa of the other end of the arc; hence find the nature of the curve given by the equation

$$s=\sqrt{(x-a)\,(x+a)}.$$

44. Show that $\phi(x, y, z) = 0$ represents a conical surface when

$$(x - a)\frac{d\phi}{dx} + (y - b)\frac{d\phi}{dy} + (z - c)\frac{d\phi}{dz}$$

vanishes identically.

Find the equation of a conical surface which shall envelop a given ellipsoid and have its vertex at a given point. What is the locus of the vertex for which the tangent cone is a cone of revolution?

45. Having given the length l of the axis, and the area of the curved surface generated by the revolution of the curve $y = f(x)$ about the axis of x, show that if $\int_a^{l+a} y^4 dx$ be a maximum, the radius of curvature at any point of the curve is one third of the normal.

46. Explain the method of obtaining the solution of the linear differential equation of the second order

$$\frac{d^2y}{dx^2} + \mathrm{P}\frac{dy}{dx} + \mathrm{Q}y = \mathrm{R},$$

where P, Q, R are given functions of x.

Solve the equation

$$\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + x^2y = e^x \cos^3 x.$$

47. Define a line of curvature on a surface. If two surfaces cut orthogonally, and if their intersection is a line of curvature on one surface, show that it is also a line of curvature on the other.

48. Explain what is meant by the integral curvature of a portion of a curved surface.

Show that the integral curvatures of the portions of the ellipsoid $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$, cut off by the cone $\frac{x^2}{a^4} + \frac{y^2}{b^4} = \frac{z^2}{c^4}$ are in the ratio of $3 - 2\sqrt{2}$ to 1.

49. Show that if F be any function of x, y, z, and S a surface bounded by a closed curve,

$$\int \mathrm{F} \, . \, \frac{dx}{ds} \, . \, ds = \iint \left(n\frac{d\mathrm{F}}{dy} - m\frac{d\mathrm{F}}{dz}\right) d\mathrm{S}$$

in which l, m, n are the direction-cosines of the normal to S at any point, and the integrals are taken round the closed curve and over the surface S respectively.

50. Obtain a general expression for determining any one of Bernouilli's numbers in terms of the successive differences of zero.

Find by means of your formula the first three of these numbers.

SUBJECT VI. THEORETICAL MECHANICS.

EXAMINER, REV. J. F. TWISDEN, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than SEVEN QUESTIONS. You may select them from any part of the paper.

1. State how to find the centre of gravity of two particles whose masses are given, and which are placed a given distance apart.
   If the masses are 5 and 7 units, and they are placed 3 feet apart, how far is their centre of gravity from each of them? (10.)
2. Two forces of 8 and 12 units act at a point A, from A to P and A to Q respectively; PAQ is an angle of 72°; find by a construction drawn to scale the number of units in the force which balances them, and the number of degrees in the angles its direction makes with AP and AQ. (12.)
3. AB is a rod that can turn freely round one end, A; the other end, B, rests against a smooth inclined plane; in what direction does the plane react upon the rod? Illustrate your answer by a diagram showing the rod, the plane, and the reaction. (10.)
4. ABCD is a square, each side of which is 2 feet long; forces of 10 and 12 pounds act from A to D and from A to B respectively; find (*a*) the algebraical sum of the moments of the forces with respect to C; (*b*) what point in BC must be fixed if the forces are to balance each other about it. (16.)

5. Describe briefly the common steel-yard, and show how to graduate it, and that the graduations are equal.
What advantage is gained by the use of a steel-yard? (14.)

6. A rod 7·5 feet long can move freely in a plane round one end; it is acted on, at right angles to its length, by a force of 35 lbs.; find the number of foot-pounds of work done by the force in one turn. How many turns must it take a minute if the force works with one horse power? ($\pi=3\frac{1}{7}$.) (14.)

7. Taking for granted the formula

$$s=Vt+\tfrac{1}{2}ft^2,$$

state the meaning of each letter in it. If a body falling freely describes a distance of 30 yards in half a second, what was its velocity at the beginning of the half second? ($g=32$.) (14.)

8. The velocity of a body is increased uniformly in each minute of its motion by 66000 yards a minute; by how many feet a second is its velocity increased in each second?
If the acceleration of a body's velocity, due to the action of a certain force, is 55 in feet and seconds, what is it in yards and minutes? (14.)

9. Define a simple pendulum, a compound pendulum, and the centre of oscillation of a compound pendulum.
If a body suspended on a horizontal axis makes 35 small oscillations a minute, what is the distance from its centre of suspension to its centre of oscillation? ($g=32$, $\pi=3\frac{1}{7}$.) (16.)

10. Describe briefly the specific gravity bottle. When the bottle is full of water it is counterpoised by 983 grains in addition to the counterpoise of the empty bottle, and by 773 grains when filled with alcohol; what is the specific gravity of the alcohol? (12.)

11. A vessel is partly filled with water, and then oil is poured in till it forms a layer 6 inches deep; find the pressure per square inch due to the weight of the liquids at a point 8·5 inches below the upper surface of the oil, assuming the specific gravity of the oil to be 0·92 and the weight of a cubic inch of water to be 252 grains. (12.)

12. Explain briefly the use of a vent-peg, and how it acts. (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on p. 51.

You are not permitted to attempt more than *eight* questions. You may select them from any part of the paper.

21. If R is the resultant of two forces P and Q acting at A, assuming the "parallelogram of forces," show that

$$R^2=P^2+Q^2+2\,PQ\cos PAQ.$$

Two forces in the ratio of 1 to 3 have a certain resultant when their directions contain a certain angle; the square of the resultant is doubled if the direction of one of the forces is reversed; find the angle. N.B. $9\sin 33^\circ 43'=5$. (25.)

22. If two forces act at a point, and their moments are taken with respect to any point in their plane, the algebraical sum of their moments will equal the moment of their resultant taken with respect to the same point. Prove this in the case when the point is so chosen that the moments of the forces have opposite signs.

Draw a square ABCD; suppose forces of P and Q units to act from A to B and from A to D respectively; find the perpendicular distance of the line of action of their resultant from C. (20.)

23. A rod without weight rests horizontally on two points, A and B, 10 feet apart; between A and B take points C, O, D, such that AC = 2 feet, AO = 4 feet, AD = 7 feet; a weight of 100 lbs. is hung at C, and one of 90 lbs. at D; find the algebraical sum of the moments with respect to O of the forces on one side of O. (20.)

24. A and B are two points a given distance apart, A below B, the line AB is of given length and inclined at a given angle to the horizon; a thread of given length has its ends fastened to A and B; a given weight is hung on the thread by a smooth hook; find the position in which it comes to rest, and the tension of the thread. (30.)

25. Given the masses and the position of two particles referred to two rectangular co-ordinates, find the co-ordinates of their centre of gravity. Write down the corresponding formulæ in the case of three or more particles.

ABCD is a square, the sides AB and AD being taken as axes of co-ordinates; masses of 1, 2, 3, 4 units are placed at A, B, C, D respectively; find the co-ordinates of the point where a mass of 5 units must be placed that the centre of gravity of the whole may be at A. Show in a diagram the position indicated by the co-ordinates. (25.)

26. A particle (weight W) is just supported on a rough inclined plane by a force P acting in a given direction; show that

$$P\cos(\beta+\phi)=W\sin(\alpha-\phi),$$

where α is the inclination of the plane, $\alpha+\beta$ the angle between P's direction and the base of the plane, and ϕ the angle of friction.

Show how to adapt the above formula to the case in which P acts horizontally. (20.)

27. Find the time in which a particle will slide down a chord drawn through the highest point of a circle whose plane is vertical.

Find the straight line down which a particle will slide in the shortest time from a given point to a given plane. (25.)

28. The mass of a particle is M lbs., and its velocity V ft. a second; find the number of foot-pounds of work it can do against a resistance.

A particle weighs 10 lbs., and moves at the rate of 1,250 feet a second; find the distance through which it could overcome a resistance of one million pounds. (20.)

29. If V is the velocity of a simple pendulum at its lowest point, show that at any time, t, after passing through the lowest point its velocity is V $\cos\frac{2\pi t}{T}$, where T denotes the time of one complete oscillation. (25.)

30. Find the moment of inertia of a rectangular lamina about an edge.

A rectangular lamina, whose shorter edges are 4 feet long, turns round one of its longer edges 50 times a minute; it weighs 441 lbs.; find its kinetic energy (*a*) in foot-poundals, (*b*) in foot-pounds. (30.)

31. If a vessel of any shape contains a liquid with a free surface, show that the pressure per square inch is constant for all points of the liquid situated in the same horizontal plane.

A sphere, whose internal radius is 1 foot, contains mercury which covers three fourths of the vertical diameter; find the resultant pressure on a horizontal plane passing through the centre of the sphere, assuming that a cubic inch of mercury weighs 3400 grains. (20.)

32. Explain how to calculate the rarefaction produced in the receiver of an air-pump, by a given number of strokes.

If after 10 strokes the mercurial gauge fell from 30 inches to 15 inches; what would have been its fall after the first five strokes? (20.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on p. 51.

You are not permitted to attempt more than *eight* questions. You may select them from any part of the paper.

41. If there are any particles in a plane, and if the mass of each is multiplied by the square of its distance from a given point, show that the sum of the products will be least when the given point coincides with the centre of gravity of the group of particles.

If the sums are taken as above with respect to two points A and B, show that the excess of the former sum above the latter equals M. AB (AN—BN); where M denotes the sum of the masses, and N the point in which AB is met by a perpendicular let fall from the centre of gravity to AB. (40.)

42. Given a couple and a force whose direction is inclined at a given angle to the plane of the couple, show how to reduce them to a couple and a force at right angles to the plane of that couple, and show that there is only one result to the reduction. (40.)

43. AB and CD are equal rods that can turn freely round a rivet, O, passing through their middle points; the ends A and C are joined by a thread of given length (so that AOC is a known angle), the plane of the rods is vertical, and the system rests with A and C on a horizontal plane; given weights (P and Q) are hung at B and D; find the tension of the thread and the stress on the rivet. (55.)

44. A uniform rod, AB, of given weight carries a given weight, P, at the end A, and rests on a given point C, being balanced by a weight at the end B; find the bending moment at a point midway between B and C. (40.)

45. In the case of a rectangular beam, slightly bent on the usual suppositions, show that—

$$6\,(\text{Greatest Bending Moment}) = QAb,$$

where Q denotes the greatest tension, A the area of the cross section, and b the depth of the beam.

Two similar rectangular beams of the same material are supported horizontally on points, one under each end; find the relation between their dimensions when the greatest tension in the one beam is twice what it is in the other. (55.)

46. AC is the base, and CB the height of a smooth inclined plane AB; D is a given point in CB produced; two particles, P and Q, are connected by a thread which rests on a smooth point at D; Q is placed on AB and P hangs freely; find, by the principle of virtual velocities, the position of equilibrium. (50.)

47. APB is a given triangle; a body, of which P is a point, has at any instant given angular velocities, ω_1 and ω_2, round axes through A and B at right angles to the plane of the triangle. By compounding the velocities of P due to these rotations, show that the resultant velocity of P is $(\omega_1+\omega_2)$ PV, at right angles to PV, where V is a point dividing AB inversely as ω_1 to ω_2. (45.)

48. P, Q, R are three particles; P and Q are connected by a thread, and Q and R by another thread; the second thread is placed on a smooth point, so that R hangs on one side and P and Q on the other side; find the tension of the thread joining P and Q. (40.)

49. Find the kinetic energy of a cylinder of uniform density turning with a given angular velocity round its axis.

If the radius of such a cylinder is 2 feet and its weight a ton, find its kinetic energy when it makes 150 turns a minute, and state in what units your answer is expressed. If the cylinder is now acted on by a tangential friction of 60 absolute units (poundals), how many turns would it make before being brought to rest? (45.)

50. Given the moments and products of inertia of any number of particles lying in a plane with reference to two rectangular co-ordinates, find their moment of inertia with reference to any axis in their plane, passing through the origin of co-ordinates.

Find the moment of inertia of a square lamina of uniform density with reference to an axis bisecting the angle between a diagonal and a side. (50.)

51. Find a general expression for the depth of the centre of pressure of any plane area.

A triangular area has one of its angular points on the surface of the water, and its other two angular points at given depths (α and β) below the surface; find the depth of the centre of pressure. (50.)

52. If a cube, whose specific gravity is 0·5, is placed in water with four edges vertical, show that its position is one of unstable equilibrium, and find the position in which it will come to rest. (50.)

SUBJECT VII. APPLIED MECHANICS.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You may not attempt *more than five* questions.

The value attached to each question is shown in brackets after the question.

1. Distinguish between *force* and *work done* by a force. How is each respectively measured?

A traction engine draws a load of 20 tons along a level road, the tractive force on the load being 150 lbs. per ton. Find the work done upon the load in drawing it through a distance of 500 yards. (15.)

2. State the mechanical law known as the *Principle of the Lever*. In a pair of pincers the jaws meet at 1½ inches from the pin forming the joint. The handles are grasped with a force of 50 lbs. on each handle at a distance of 8 inches from the pin. Find the compressive force on an object held between the jaws, and also the pressure upon the pin. (15.)

3. Define the pitch circle of a toothed wheel. When two pitch circles, A and B, of diameters 2 and 3 respectively, roll together, prove that the angular velocity of A is to that of B as 3 to 2.

   Three spur wheels, A, B, C, with parallel axes, are in gear. A has 8 teeth, B has 32 teeth, and C has 42 teeth. How many turns will A make upon its axis while C goes round 8 times? Why is B termed an *idle* wheel? (15.)

4. Explain the construction and principle of action of a weighing machine in which both scale-pans are supported from below, without suspending chains. Sketch the arrangement. (15.)

5. Make a vertical longitudinal section through the *movable* or loose head-stock of a lathe, showing precisely the manner in which a screw and nut are applied to produce the necessary movement of the centre which supports the work. Name the materials of which the several parts are made. (20.)

6. Sketch and describe an arrangement for driving the table of a planing machine by means of a screw, so that the table may travel 50 per cent. faster in the return than in the forward or cutting stroke. Why is a square threaded screw employed in such a machine? (20.)

7. Describe, with a a sketch, the spring-barrel and fusee of a clock. Explain the principle on which the fusee acts, and mention some further instances of the useful application of this contrivance. (15.)

8. The base of a rectangular tank for holding water is a square, 16 square feet in area. The sides of the tank are vertical, and it holds 250 gallons of water when quite full. Find the depth of the tank and the pressures on each side and on the base when quite filled with water. The weight of a gallon of water is 10 lbs., and the weight of a cubic foot of water is 62½ lbs. (20.)

9. Explain the construction and action of a condensing syringe for pumping air into a vessel. Sketch a longitudinal section through the cylinder and valves. Why does one end of the cylinder become heated when the pumping goes on rapidly? (15.)

10. A bar of teak, 1 inch square, and 12 inches between the supports, breaks with a load of 820 lbs. when hung at its centre. Find the breaking load at the centre of a bar of teak, 3 inches broad and 3 inches deep, and 7 feet between the supports. If the bar be 2 inches broad instead of 3 inches, what should be its depth in order to support the same weight at the centre. (20.)

11. Write down the formula for the amount of energy stored up in a given weight when moving with a given velocity. Describe, with a sketch, the action of a fly-press. If each ball of the press weighs 50 lbs., and the work stored up in the balls is 400 foot-pounds, find the velocity with which they are moving. Take the number 32 to represent g. (20.)

12. Sketch a vertical section through the cylinder and pump of a hydrostatic press, showing the necessary valves and connections. Sketch separately the collar for packing the ram, and explain why it is so efficient. How is the pressure taken off the object under compression when required: sketch the arrangement? What is the proportion of the diameters of the plunger and ram when the mechanical advantage gained thereby is 100 to 1, neglecting friction? (20.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not attempt more than *five* questions.

The value attached to each question is shown in brackets after the question.

21. Four cwts. of material are drawn from a depth of 80 fathoms by a rope weighing 1·15 lbs. per linear foot; how many units of work are expended? What horse-power would be required to raise the material in 4½ minutes? (25.)

22. Set out a form of cam which, when acting on a bar by uniform rotation, will cause the backward and forward motion of the bar to have an interval of rest between each. Describe some other method of obtaining an intermittent motion of this kind. (30.)

23. Describe the construction of a hand printing-press worked by the Stanhope levers. Explain the action of this combination of levers. (35.)

24. A belt having a linear velocity of 350 feet per minute transmits 5 horse-power to a pulley round which it passes. Find the tension of the belt on the driving side, supposing it to be double that on the slack side. (30.)

25. A sheer-legs is formed of two sheer-poles, BC, DC, each 25 feet in length, and secured to a base plate in the ground at B and D. The wire guy or tension rope AC is attached to the ground at a point A, which is 60 feet distant from BD. The perpendicular from the top C of the poles meets the ground at a distance of 10 feet from the centre of the line BD, which is 15 feet long. Find by measurement or otherwise the tension in tons on the guy when a weight of 20 tons is suspended. (40.)

26. What do you understand by the terms *strain*, *stress*, and *modulus of elasticity*?

A tie rod 100 feet long, and of 2 square inches sectional area, is stretched three quarters of an inch under a tension of 32,000 lbs. What is the intensity of the stress, the strain, and the modulus of elasticity under these circumstances? (35.)

27. What is an epicyclic train of wheels? Two spur wheels A and B, whose diameters are 2 and 3 respectively, are in gear with an annular wheel, C, whose diameter is 8. The wheels A and C have a common axis, but B is carried by an arm centred on the axis of A. If A makes five revolutions while C makes one revolution, both in the same direction, find the angle described by the arm during this time. (40.)

28. A fly-wheel weighs 2½ tons and its mean rim has a velocity of 40 feet per second. If the wheel gives out 10,000 foot-pounds of energy, how much is its velocity diminished? (35.)

29. A circular water tank is 20 feet in diameter and 25 feet deep. It is constructed of 6 rings of cast iron plates. Find the *total* stress on any vertical section of the bottom row of plates made by a plane passing through the axis of the cylinder, neglecting any assistance afforded by the flanges or connection with the bottom plate. (40.)

30. What is the object of a relief valve in an hydraulic crane, and where is it placed? Sketch a longitudinal section through the cylinder and ram of a crane working at two powers. Explain the mode of action. (40.)

31. Describe Weston's differential pulley.

If the weight is to be raised at the rate of 5 feet per minute, and the diameters of the pulleys of the compound sheave are 7 and 8 inches respectively, at what rate must the chain be hauled? (40.)

32. Describe, with sketches, three different forms of reversing motion in common use, where machinery is driven by steam power. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

41. A toothed wheel drives a pin wheel; investigate the proper form for the curves of the teeth. The diameter of each pin being known, how do you proceed to set out the teeth, preserving their theoretical outline? Sketch the necessary diagram. (60.)

42. Construct a cam which shall impart to a rod a *uniformly increasing* velocity during one half the stroke, and a *uniformly decreasing* velocity during the remaining half stroke. (60.)

43. In a four-bar motion ABCD, the fixed centres are A and D, the arms AB, DC are cranks, and BC is the connecting link. It is given that AB = BC = 12 inches, and that ABC straightens itself once during each revolution of AB. Find the lengths of AD and DC in order that the link BC may oscillate relatively to AB through one right angle once during each revolution of AB from the position where ABC is a straight line. (70.)

44. Establish the formula for the moment of resistance to bending of a beam of rectangular transverse section. Find the greatest load that may be uniformly distributed on a cast-iron girder having top and bottom flanges united by a web of the following dimensions—width of upper flange 3 inches, of lower flange 9 inches, total depth 12 inches, thickness of each flange and of the web being 1 inch, distance between the points of support 10 feet—when the greatest admissible stress in the compression flange is 3 tons per square inch, and that in the tension flange is 1½ tons per square inch. (75.)

45. Describe, with sketches, the chronometer escapement, pointing out the reasons for the particular construction of certain of the working parts. What theoretical reasons do you assign for the excellent performance of this escapement in practice? (65.)

46. Describe a frictional dynamometer having a pendulum compensating lever. In what way may the force acting on the point of suspension of the pendulum be ascertained? When this force is known, how do you obtain the true horse-power transmitted? (70.)

47. Describe Peaucellier's combination of linkwork for drawing a straight line, and prove geometrically that the path of the describing pencil is a straight line. (55.)

SUBJECT VIII. SOUND, LIGHT, AND HEAT.

EXAMINERS, PROFESSOR W. GRYLLS ADAMS, M.A., F.R.S.,
AND PROFESSOR OLIVER J. LODGE, D.Sc., LL.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *eight* questions. Of these not more than *four* may be selected from the same section.

The value attached to each question is the same.

Section I.

1. State exactly what you mean by the "density" of a substance, and explain what you understand by its "elasticity." Is the elasticity of water greater or less than that of air? How would you prove to anyone that your answer is correct?

2. Explain any method by means of which the ticking of a watch may be made audible to a person at the other end of a large room.

3. What variety of notes can you get out of a stretched string, without altering its tension or length? What will be the effect of halving its length by a fixed bridge?

4. Upon what physical properties do (1) the loudness (2) the pitch of a musical note depend? Two organ pipes of the same length are one of them open and the other closed; how are their notes related as regards pitch?

5. Describe the state of disturbance of the air in a pipe closed at one end, when it resounds to a tuning-fork which is held over it. State the relation between the length of the pipe, the pitch of the note, and the velocity of sound in air.

Section II.

6. What is meant by an image of an object? Why are some images called real, and others virtual? Explain and illustrate by a sketch the formation of an image of each kind by means of a concave mirror.

7. Give some method of comparing the brightness of two sources of light, and describe the essential parts of the apparatus employed.

8. A candle is placed at a given small distance in front of an ordinary looking-glass made of thick plate-glass quick-silvered on the back, and a person looking obliquely into the mirror sees several images of the candle; explain this, and show the exact positions of the images by a diagram.

9. An arrow 4 inches long is placed 10 inches in front of a convex lens whose focal length is 4 inches. Illustrate by a figure, and find the position and length of the image.

10. One piece of glass appears dark red, and another appears dark green, when held up to the light; explain why when they are both put together no light can be seen through them.

Section III.

11. Explain exactly the nature of boiling. Is it possible to make luke-warm water boil without heating it, and, if so, how?

12. Why does a block of ice take so long to melt, even in a warm room? Suppose heat continually poured into it, enough to raise the temperature of a quantity of water equal to the solid part of block two degrees centigrade in a minute, how long would the block take to melt? [Latent heat of water = 80.]

13. What circumstance determines whether a towel exposed to the air shall dry or shall become damp? Why does a damp cloth exposed to draught become very cold?

14. What do you know concerning the nature and formation of clouds and rain?

15. What is meant by saying that the "specific heat" of water is thirty times as great as that of mercury? If a pound of boiling water be mixed with 3 lbs. of ice-cold mercury, what will be the temperature of the mixture?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions. Of these not more than *four* may be selected from the same section.

The value attached to each question is the same.

Section I.

21. How can Boyle's law for gases be verified by direct experiment?

22. Define "elasticity" and "density," and explain how the velocity of sound depends upon them.

23. What effect does pumping half the air out of a closed vessel produce on the velocity of sound passing through it? Also what is the effect of compressing the air? (The temperature in both cases is supposed to be constant.)

24. Explain the occurrence of "beats" when two notes nearly of the same pitch are sounded together. How comes it that open organ pipes nearly an octave apart give beats? How comes it that feeble beats are also heard even from two stopped pipes, or two tuning forks, when nearly an octave apart in pitch?

25. Give the relations of the number of vibrations of the successive notes of the diatonic scale and the Pythagorean scale, and explain for what purpose each scale is especially suitable and why.

Section II.

26. Explain the law of refraction of light at a plane surface according to the wave theory.

27. Describe the measurements which are required and the method of determining the refractive index of a transparent substance in the form of a prism.

28. Find the magnifying power of a simple lens of one inch focal length, placed close in front of an eye whose distance of distinct vision is ten inches. Illustrate with a figure.

29. An iron ball is made white hot, and its spectrum examined by a spectroscope. What will be the nature of the spectrum seen? Again, a piece of iron is used as one of the poles in the electric arc and the spectrum examined. In what respects do the two spectra differ from one another? To what molecular conditions do you suppose the difference to be due?

30. A convex lens is pressed on a piece of plate glass. Explain and state the laws of the phenomena which are observed near the point of contact of the lens and plate.

Section III.

31. Define what is meant by "the latent heat" of water, and state exactly how you will proceed to measure it experimentally.

32. What is meant by saying that heat is a form of energy? How has the amount of energy corresponding to a unit of heat been determined?

33. The temperatures in the boiler and condenser of a steam engine are 150° and 50° respectively. What proportion of the heat supplied to the engine will be utilized if the engine is a perfect engine?

34. How can the absolute expansion (*a*) of mercury (*b*) of any other liquid, be determined?

35. What is the meaning of the term "Humidity" or "Hygrometric state," as applied to the atmosphere? Give a short description of the instruments that are commonly employed for finding the state of the air with respect to moisture. The dew point on a certain day being found to be 12° C., and the temperature of the air being 16·5° C., find its humidity, given that the maximum pressure of aqueous vapour at 12° is equivalent to 1·046 cm. of mercury, while that at 16° is 1·364 cm., and that at 17° is 1·442 cm.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are expected to attempt all the questions.

The value attached to each question is the same.

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41. The specific gravity of a certain gas, under a pressure of 75 centimetres of mercury and at 0° C., is one-thousandth that of water. What is the velocity of sound in it at that temperature? What is it also at the temperature 100°? Examine whether altering the pressure on the gas will affect the velocity.

[Take the ratio of the two specific heats as 1·4.]

42. A system of parallel rays is incident on a refracting sphere. Prove that there is a certain angle of incidence for which the deviation is a maximum, when the pencil of rays is once internally reflected. Explain the application of this proposition to the theory of the rainbow.

43. Fine parallel lines are ruled closely at regular intervals on a glass plate; explain precisely why and where spectra are formed when the plate is illuminated by a beam of light coming through a lens from a slit arranged parallel to the ruled lines. Explain the effect on these spectra of the closeness of the ruling and the breadth of the ruled space.

44. Explain the difference between the adiabatic and the isothermal elasticities of a substance; and show how to determine the ratio of these two elasticities for common air experimentally.

45. Explain exactly the adhesion of two pieces of ice when pressed together at the melting point and then released. Calculate the effect of an extra atmosphere of pressure on the melting point of a substance which contracts on solidifying by one-sixth of its volume in the liquid state, whose latent heat is 40 units, whose ordinary freezing point is 27° C., and whose specific gravity when liquid at this temperature is 1·2.

Practical Examination.

I.

1. Find the specific heat of the mixture of alcohol and water.
2. Compare the vapour pressure at the temperature of the room of the mixture of sulphuric acid and water.
3. Determine by a diffraction grating the wave lengths of three of the lines in the spectrum of the given substance.
4. Determine the rotation of the plane of polarization produced by the given plate of quartz, using red light; measure the thickness and so find the rotation produced by one millimetre of quartz.

II.

1. Find the boiling points of three brine solutions having strengths of 5, 15, and 25 of salt to 100 of water.
2. Determine the index of refraction of the lens given you for sodium light.
3. Arrange the two lenses given you so as to produce a real image of the object magnified four times, and show how to test your result.
4. Determine the absolute pitch of the tuning fork given you by finding the ratio and difference of two notes that are nearly alike.

SUBJECT IX. MAGNETISM AND ELECTRICITY.

EXAMINERS, PROFESSOR A. W. REINOLD, F.R.S., AND
PROFESSOR A. W. RÜCKER, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than *eight* questions.

You may select only *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

1. An astatic combination of two magnets is injured so that the magnets are at right angles instead of parallel to each other. If it be suspended as usual, what position will it assume with regard to the magnetic meridian? Illustrate your answer with a diagram showing the forces which act upon the magnets.

2. A strong bar magnet is placed on a table with its axis lying in the magnetic meridian and with its north-seeking pole towards the north. State in what direction a compass needle points (1) when placed immediately over the centre of the bar magnet; (2) when gradually raised vertically upwards.

   N.B.—The compass needle can only turn about its pivot in a horizontal plane.

3. Two bars of soft iron are so placed to the east and west of the north pole of a compass needle that the needle still points north and south. If the iron to the east of the needle be replaced by a bar of hard steel of exactly the same size and shape as itself, will the direction in which the magnet points be altered? If so, in which direction will it move, and why?

4. What is meant by saying that the magnetic dip at London is 67° 30′?

   State in general terms at what places on the earth's surface the magnetic dip is least.

Frictional Electricity.

5. How would you prove to a class that there are two kinds of electricity?
6. A rod of sealing wax is rubbed with dry flannel. An uncharged pith ball suspended by a silk thread is attracted when the sealing wax is brought near to it, but is unaffected by the flannel. Would you conclude from this experiment that when sealing wax and flannel are rubbed together the sealing wax only is electrified? Give reasons for your answer.
7. When the handle of an ordinary frictional machine is turned, sparks can be drawn from the prime conductor. Explain carefully how the prime conductor becomes charged with electricity.
8. A sharp point attached to a conductor A is held near an insulated charged conductor B. What will be the effect on B if A is (1) insulated, (2) uninsulated?
9. The inner coating of a Leyden jar is connected by a wire with the prime conductor of an electrical machine and also with a gold leaf electroscope. If the jar rests upon a sheet of glass, a quarter of a turn of the machine produces a large divergence of the leaves of the electroscope. If the glass be removed, ten turns of the handle are required to produce the same deflection. Explain this.

Voltaic Electricity.

10. An insulated positively electrified gold leaf hangs half way between two vertical insulated and unelectrified copper plates, A and B, to each of which a copper wire is attached. If plates of zinc and copper, which are partly immersed in dilute acid, are touched by the wires attached to A and B respectively, and if afterwards the wires are both dipped into the acid, describe the movements of the gold leaf in each case.
11. What are the materials used in the construction of a Daniell's cell, and what chemical changes occur in the cell when in action?
12. Plates of platinum and copper are dipped into a solution of copper sulphate. What effects are produced upon them if a current is passed through the liquid from the copper to the platinum?
13. A current flows through a copper wire, which is thicker at one end than at the other. If there is any difference either (1) in the strength of the current at, or (2) in the temperature of, the two ends of the wire, state how they differ from each other, and why.
14. An insulated copper wire is wound round a glass tube, AB, from end to end, and a current is sent through it, which to an observer looking at the end A, appears to go round in the same direction as the hands of a watch. A rod of soft iron is held (1) inside the tube; (2) outside but parallel to the tube. What will be the magnetic pole at that end of the bar which is nearest to the observer in each case?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *eight* questions.

You may only select *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

21. The north-seeking poles of two equal and equally magnetised magnets are attached to the ends of a light bar of wood, so that the magnets are parallel to each other and at right angles to the bar, and the south-seeking poles are on opposite sides of it. If the whole be suspended by a thread, so that the bar and the magnets lie in a horizontal plane, what position will the bar take up with respect to the magnetic meridian? Give reasons for your answer.

22. You are given two bar magnets, and you are told that the magnetic moment of one is twice as great as that of the other. How will you, by means of a torsion balance, test the correctness of this statement?

23. An iron ball is held due north of a compass needle. Describe the motions of the needle as the ball is carried round it in a circle in the direction north, east, south, west, north.

24. A bar magnet which can move only in a horizontal plane is caused to vibrate at three different stations, A, B, and C. At A it makes 20 vibrations in 1 minute 30 seconds; at B, 25 vibrations in 1 minute 40 seconds; at C, 20 vibrations in 2 minutes. Find three numbers proportional to the forces which act upon the magnet at the three places.

Frictional Electricity.

25. Two conducting spheres, the diameters of which are in the proportion 1 : 2, are charged with equal quantities of positive electricity. They are placed *in turn* near to another positively charged sphere (S), so that the distances between the centres are in each case the same. Find the ratio of the forces with which S is in each case repelled, assuming that the charges are uniformly distributed over the spheres.

26. Two charged insulated metal spheres are connected by a long wire. If their radii are 1 and 2 feet respectively, on which is the density of the charge the greater, and what is the relation between the densities on the larger and smaller respectively?

27. Two Leyden jars are charged, one with 5, the other with 10 turns of an electrical machine, the outer coatings of the jars being connected with the ground. If in the second jar (which receives the larger charge) the tinfoil surface is twice as great, and the glass is twice as thick as in the first, compare the quantities of heat produced by discharging them.

28. Two insulated metal balls, of which one only is electrified, are placed near each other. If an unelectrified plate of paraffin is introduced between them, how is the distribution of the electricity on the balls altered?

29. An electrophorus after being charged in the ordinary way, is placed on the cap of an electroscope. The metal cover is then placed on the electrophorus by means of its insulating handle, and, lastly, the cover is momentarily touched with the finger. Describe and give reasons for the behaviour of the gold leaves in each of these three cases.

Voltaic Electricity.

30. Six similar cells are arranged in series, and the circuit completed through a coil of wire and a galvanometer. The resistances of the battery, coil, and galvanometer are 10, 50, and 20 ohms respectively. If the difference of potential between the terminals of the galvanometer be 2 volts, what is the electromotive force of each cell of the battery?

31. A wire, the total resistance of which is 4 ohms, is bent into the form of a square, ABCD, the loose ends being soldered together. Find the resistance of the system when a current enters at B and leaves at D. Will it be modified if the corners, A and C, are connected by another wire?

32. A current flows through two troughs, which are connected in multiple arc, and contain a solution of copper sulphate. If all the circumstances of the two paths which are thus open to the current are the same, except that the metal plates by which it enters and leaves the liquid are, in the one case copper, and in the other platinum, will the currents be equally strong in the two troughs? Give reasons for your answer.

33. A tangent galvanometer is placed with its coil perpendicular to the magnetic meridian. When no current is passing through it, the needle when set in vibration oscillates 10 times in 15 seconds. Will the rate of vibration be altered when a current is passing through the coil, and if so, will it be increased or diminished?

34. A wire is held in the magnetic meridian over a compass needle, and a current is passed through it of sufficient strength to deflect the needle through an angle, which cannot be distinguished from a right angle. Show that when the needle is thus displaced the current tends to lift it from its pivot.

Honours Examination.

Full marks can only be got by answering all the questions.

41. Describe the operations necessary for the determination of the moment of a given bar magnet in absolute measure.

42. Discuss methods of finding the specific resistance of a material, of which a bar, 2 metres long, and 1 square centimetre in cross section, is given.

43. The terminals of the secondary of a Ruhmkorff coil are connected with the quadrants of a charged quadrant electrometer. Discuss the behaviour of the electrometer when the coil is in action. Will any change in the indication of the instrument be observed when one pair of quadrants is put to earth?

44. Describe a method of comparing the coefficient of self-induction of a coil with the coefficient of mutual induction between it and another coil.

45. Write a short essay on the source of the energy of the electric current in a thermoelectric circuit.

Practical Examination.

I.

Compare the moments of the two magnets supplied to you by the two following methods:—

(1.) By means of the deflections they produce in a suspended magnet;

(2.) By comparing their times of vibration and determining their moments of inertia by weighing and measurement.

II.

1. Measure the resistances of the wires supplied to you by means of the Post Office bridge. Determine their dimensions and the specific resistances of the materials of which they are composed.

2. Compare the resistances of two wires by means of the ballistic galvanometer. For this purpose you are supplied with a condenser, battery, galvanometer key and wires.

3. You are given 10 Groves cells, a ballistic galvanometer, a shunt without self-induction, a condenser and key. Observe the deflection produced by discharging the condenser through the galvanometer after it has been charged by each of the 10 cells in turn. Shunt the galvanometer to one-tenth and observe the deflection produced when the condenser has been charged by the 10 cells arranged in series. The mean of the 10 deflections obtained when the galvanometer was not shunted must be either greater, equal to, or less than the deflection obtained by using all 10 cells when it was shunted. Discuss, in view of the results of your experiments, the relation between them.

4. Name and give the formula of a salt, and describe how you would prepare it. (8.)

5. What do you understand by the density of a gas? The volume of a given weight of a gas has to be calculated at the standard temperature and pressure. What does this mean? (13.)

6. How could you prove that chlorine is a constituent of common salt and of hydrochloric acid? Calculate the per-centage composition of these two substances. (13.)

7. Why are the nitrogen and oxygen in nitrous oxide said to be in a state of combination, and why in air are they said to be in a state of mixture? (12.)

8. Name the principal gases in the air? How is their amount determined? (10.)

9. How many cubic centimetres of oxygen and of hydrogen are obtainable from 10 grams of water? (15.)

10. What sulphur compounds occur in nature? Describe the chief properties of sulphur, and state how it may be converted into its various allotropic modifications. (11.)

11. Express in the form of equations the action of—
    (1.) Heat upon ammonium nitrate.
    (2.) Hydrogen upon (*a*) cold, (*b*) hot copper oxide.
    (3.) Sulphuric acid upon ferrous sulphide.
    (4.) Hydrochloric acid upon chalk.
    (5.) Sulphuric acid upon nitre. (13.)

12. How is sulphuretted hydrogen prepared? What are its properties, and what is formed when it burns in air? (9.)

Alternative First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

21. Some soil is shaken up with distilled water. How could you prove that some of it has been dissolved? (8.)

22. Describe an experiment to show that when a substance burns in air, oxygen combines with the burning body. (12.)

23. What is the chemical nature of fat? How may it be converted into soap? What is the difference in chemical composition between "hard" and "soft" soap? Describe the action of soap upon hard water. (15).

24. What happens when sulphur burns in air? How do you account for the peculiar smell of burning sulphur? (11.)

25. What is the composition of limestone? Name other substances of the same composition. Explain what occurs when limestone (1) is strongly heated; and (2) is placed in dilute hydrochloric acid. (13.)

26. How could you prove that hot water dissolves more nitre than cold water? (10.)

27. Of what chemical elements is sugar composed? What happens when a solution of sugar is mixed with yeast? (10.)

28. What is the chemical nature of clay, gypsum (plaster of Paris), glass and chalk? (13.)

29. What is the principal source from which tartaric acid is obtained? Of what elements is it compared? Describe what happens when it is added to a solution of carbonate of soda. (13.)

30. In what respects does metallic lead differ from red lead? How can the one be converted into the other? (9.)

31. How can you obtain alcohol from beer? What is proof spirit? (13.)

32. Of what metals is a penny composed? What is the difference between an alloy and an amalgam? (9.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

$H = 1. \quad O = 16.$

41. 2·0876 grams of hydrogen when passed over heated oxide of copper yielded 18·7406 grams of water. Calculate the atomic weight of oxygen. (12.)

42. How would you convert sodium carbonate into sodium sulphite; carbon dioxide into carbon monoxide; iodine into iodic acid; fluorspar into hydrofluoric acid? (12.)

43. How could you prove that the molecule of water contains 2 atoms of hydrogen? (15.)

44. Of what value is a knowledge of the specific heat of an element in determining its atomic weight? (11.)

45. How could you prepare the chloride, sulphide, and sulphate of manganese from black oxide of manganese? (12.)

46. How are the different kinds of phosphoric acid prepared? Give the formulæ of the corresponding sodium phosphates. (15.)

47. Describe the methods of converting common salt into soda ash, soda crystals, and caustic soda. (10.)

48. What is the action of water on the following substances: bismuth chloride, silicon fluoride, phosphorus pentachloride, red-hot iron? (12.)

49. The molecules of most elementary substances consist of two atoms. Name the exceptions to this law. (11.)

50. How is bleaching powder prepared? Give its formula and explain how it acts as a bleaching agent. (11.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

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61. What is meant by the atomic volume of a substance? How is it determined? (13.)

62. Describe the experiments by which the constitution of ozone has been definitely established. (14.)

63. When equivalent quantities of soda, nitric acid, and sulphuric acid mutually react in a dilute aqueous solution, two-thirds of the soda combines with the nitric acid and one-third with the sulphuric acid. How has this fact been ascertained? (18.)

64. Give an account of the present state of knowledge of the theory of illuminating flames. Why is the flame of the Bunsen lamp non-luminous? (18.)

65. Describe the experiments by which Victor Meyer has shown that the molecule of iodine suffers dissociation at high temperatures. (16.)

66. How can the density of a gas be determined from its rate of diffusion. If a gas diffuses 1·0143 times as rapidly as air, what is its density? (15.)

67. Describe in detail the Weldon chlorine process. (16.)

68. Draw up a scheme for the estimation of carbon (free and combined), sulphur, phosphorus, silicon, in cast-iron. (17.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

ELEMENTARY STAGE.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.Sc., PH.D., F.R.S.

INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of your question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

1. How can ferrous sulphate, ferric chloride, and hydrated ferric oxide be prepared from iron wire? (15.)
2. Two solutions are given to you. One contains a salt of lead; the other hydrochloric acid. What tests would you apply to identify the lead and the hydrochloric acid? (10.)
3. Draw and describe an apparatus to show that when dry hydrogen burns in air, water is formed. (10.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the elementary stage examination is confined to the qualitative analysis of two mixtures, each containing not more than two metals and one acid from the following list:—

Lead, mercury, bismuth, iron, calcium, potassium, ammonium, carbonic acid, nitric acid, sulphuric acid, hydrochloric acid.

Two and a quarter hours are allowed for this part of the examination.

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

Advanced Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.Sc., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

Whenever possible you are to express reactions in equations.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

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1. Give a sketch of the apparatus you would employ to make pure carbonic oxide from oxalic acid, and explain the theory of the process. (10.)

2. Give equations representing the action of sulphuretted hydrogen upon solutions of the following substances:—Arsenious acid; silver nitrate; caustic potash; ferrous sulphate; ferric chloride; bismuth chloride; corrosive sublimate. (15.)

3. Describe the preparation of a solution of hydriodic acid from phosphorus and iodine. Give equations representing the changes which occur. (10.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Advanced Stage.

The two test substances supplied for qualitative analysis to candidates in the advanced stage consist of mixtures, each of which may consist of not more than two simple salts, the materials of which may be selected from the following list:—Potassium, sodium, ammonium, magnesium, calcium, strontium, barium, aluminium, chromium, zinc, manganese, iron, cobalt, nickel, arsenic, antimony, tin, cadmium, copper, bismuth, mercury, lead, silver, hydrosulphuric acid, hydrochloric acid, hydrobromic acid, hydriodic acid, sulphurous acid, nitric acid, chloric acid, carbonic acid, hydrofluoric acid, phosphoric acid, sulphuric acid.

Three and a quarter hours are allowed for this part of the examination.

Honours.

Three substances are supplied to each candidate in Honours, two for qualitative and the third for quantitative analysis.

The two substances supplied for qualitative analysis consist of mixtures, which must be examined for all the bodies named above in the instructions for the advanced stage.

The substance for quantitative analysis need not be analysed qualitatively.

QUANTITATIVE ANALYSIS.

Each candidate is furnished with a numbered bottle containing a powder in which lead has to be quantitatively determined.

The results must be expressed in grams of lead (Pb) in 100 grams of the powder (Pb = 206·4).

The candidate is recommended to weigh out, *accurately*, from 1 to 2 grams of the powder, for the purpose of analysis.

The candidate must not omit to place upon his worked paper the number attached to the bottle containing the powder he has analysed.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XI. ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.Sc., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Whenever possible, you are to express the reactions by equations.

You are to give such numerical details as will show the mode of calculation.

The value attached to each question is indicated by a number placed at the end of the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

Ag = 108. C = 12. O = 16. H = 1.

1. What is the weight of carbon and of hydrogen contained in 10 grams of silver acetate? (13.)
2. What is the difference between spirits of wine and wood-spirit? If these bodies are oxidised what is the composition of the substances formed? (12.)
3. Describe how one of the following bodies can be prepared synthetically: alcohol, acetylene, marsh-gas. (13.)
4. When aldehyde is warmed with silver nitrate solution, metallic silver is formed; when carbon dioxide is heated with sodium and sand, sodium oxalate is formed; and when alcohol is heated with dilute sulphuric acid, ether is formed. Give equations representing these reactions. (15.)
5. What volume of air containing 21 per cent. of oxygen is required to burn a litre of marsh-gas? (13.)
6. How are chloroform and carbon tetrachloride usually prepared? How could you distinguish the one from the other? (10.)
7. What do you understand by "substitution"? Give examples. (9.)
8. How could you prepare acetic acid from sugar of lead? By what tests could you recognise the presence of acetic acid in aqueous solution? (9.)
9. How do you prepare cyanogen? Describe its properties. Why is it called a compound radical? (10.)
10. Calculate the empirical formula of a substance which has the following percentage composition:—

Carbon - -	54·54
Hydrogen - -	9·10
Oxygen - -	36·36
	100·00

(11.)

11. What is the difference between a saturated and a non-saturated hydrocarbon? What is the experimental proof that a hydrocarbon is saturated or non-saturated? (13.)
12. What is "Sweet Spirits of Nitre"? How is it made? (8.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *eight* questions.

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21. Why is acetic acid represented by the following formulæ? $C_2H_3O_2.H.$, $CH_3CO.OH$; and $C_2H_3O.OH$? Give the experimental evidence upon which these formulæ are based. (15.)

22. Explain the methods of determining the molecular weights of non-volatile acids and bases. Illustrate your description by the examples of oxalic acid and strychnine. (12.)

23. Describe the methods of determining sulphur and phosphorus in an organic body. (10.)

24. What is the constitutional difference between compounds of the fatty series and those of the aromatic series? (10.)

25. Describe the preparation of aniline from benzene. How would you recognise the presence of aniline? (10.)

26. An alcoholic solution of potassium bromide is heated with ethylene cyanide, and the liquid afterwards boiled with caustic potash. Describe the changes which occur, and the principal compound formed. (12.)

27. Describe a process by which you can pass from the methylic to the ethylic series. (12.)

28. Calcium acetate is heated alone; it is also heated with calcium formate. Give the formula and properties of the body formed in each case. (12.)

29. Give the general methods of preparation of the anhydrides of the fatty acids. (12.)

30. A hydrocarbon which has the vapour density 50 gave the following numbers on analysis:—
    0·3500 gram gave 1·0754 gram CO_2 and 0·5050 gram water.
    Calculate the formula of the body. (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt *six* questions.

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41. What is a glucoside? Name the bodies of this class in madder, bitter almonds, indigo, quercitron, and willow bark. Into what substances may they be resolved on hydrolysis? (17.)

42. Name and give the most characteristic properties of the chief alkaloids of opium, cinchona bark, tobacco, hemlock, and nux vomica. (16.)

43. Give an account of Emil Fischer and Tafel's synthetical experiments in the sugar group. (18.)

44. Describe any fatty compounds that can be obtained from benzene compounds by processes of oxidation or of joint oxidation and chlorination. (18.)

45. How can indoles be obtained from phenylhydrazine derivatives? (16.)

46. Describe how you can determine by optical means the amount of cane-sugar in a solution. (13.)

47. Name the chief proximate constituents of blood? How can they be isolated? (15.)

48. Give some account of the connection which has been traced between the optical characters of a body and its chemical constitution. (14.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

Examiners, W. J. RUSSELL, Esq., Ph.D., F.R.S., and PROFESSOR T. E. THORPE, B.Sc., Ph.D., F.R.S.

General Instructions.

If the rules are not attended to, the paper will be cancelled.

You must take the same stage in this written examination that you are taking in the examination in Practical Analysis in this subject.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *two* questions.

1. Describe how you would carry out the following experiments:—
   (*a*) The preparation of formic acid from oxalic acid.
   (*b*) The preparation of acetic acid from alcohol. (15.)
2. What are the tests for tartaric and oxalic acids? Give equations. (10.)
3. How would you obtain pure ether from a mixture of alcohol and ether? (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *two* questions.

21. What is meant by fractional distillation? How is it carried out? Sketch the apparatus used. (15.)
22. A sample of cane sugar is suspected to contain glucose. How could you prove if such were the case? (10.)
23. How could you show that glycerine can be obtained from suet? (10.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the Elementary Stage Examination is confined to the qualitative analysis of two mixtures, which may each contain not more than two of the following constituents, together with an inorganic base or bases which need not be determined :—

Formic acid, acetic acid, oxalic acid, tartaric acid, salicylic acid.

Two and a quarter hours are allowed for this part of the examination.

Advanced Stage.

The practical work for the advanced stage examination is confined to the qualitative analysis of two substances, each of which may contain not more than two organic bodies selected from the following list :— Hydro-cyanic acid, oxalic acid, acetic acid, tartaric acid, citric acid, salicylic acid, grape sugar, starch, morphine, and urea.

Any inorganic bodies present need not be determined.

Three and a quarter hours are allowed for this part of the examination.

Honours.

The examination in Honours consists of a qualitative analysis of the two mixtures supplied, and of the determination of the percentage of nitrogen contained in the organic substance distributed for this purpose.

The bottle marked (A) contains a substance in which the percentage of nitrogen is to be determined by Organic Analysis.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XII. GEOLOGY.

EXAMINER, H. W. BRISTOW, F.R.S., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

You are permitted to attempt *eight* questions only.

1. Draw a section showing Fault, Outlier, Synclinal, Unconformity, Inlier. (20.)
2. What mineral substances are carried down by rivers? What becomes of these when the rivers reach the sea? (20.)
3. How does a "mineral" differ from a "rock"? Mention three examples of each. (12.)
4. Give a brief description of the Triassic rocks of England. (12.)
5. Enumerate the genera of Mollusca by means of which you would be able to distinguish deposits formed in fresh water from those formed in salt water. (12.)
6. Describe the mode of formation of limestone rocks. (8.)
7. Explain the theory of Artesian Wells, and illustrate your answer by means of a diagram. (8.)
8. What are soils? Explain their origin. (8.)
9. What is the difference between Slate and Shale? (8.)
10. In the case of a cone-shaped hill, how would you determine if this were a volcano? (8.)

11. To what is the colour of red rocks generally due? (8.)

12. What is the difference between Sandstone, Quartz, and Quartzite? (8.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on p. 84.

You are permitted to attempt *six* questions only.

21. What is Unconformability? Draw a section showing any district in England to illustrate your answer, naming the district illustrated, and the rocks shown. (45.)

22. State what you know as to the evidence for a high temperature in the Earth's interior. (45.)

23. Briefly describe the upper limit of the Cambrian group of rocks, as defined by various authorities. (33.)

24. Explain how a vertical shaft may intersect the same bed of Coal more than once. Explain, also, how the shaft may fail to find another seam known to be present in that district within the vertical range traversed by the shaft. (33.)

25. If well-rounded blocks of stone cover the surface of a certain area, how would you ascertain if these have been transported from a distance, or have been produced by weathering on the spot? In the latter case, what rocks are most likely to yield such blocks? (22.)

26. Describe the beds which usually come between the Oxford and Kimeridge Clays. In what part of England are these beds absent, and how may the clays be then distinguished? (22.)

27. Describe the rocks to which the term Syenite has been applied. (22.)

28. Roughly sketch a map of England and Wales, marking on it the area occupied by the Cretaceous rocks, *or* by the Silurian and Cambrian rocks. (22.)

29. A sample of clay containing Fossils may be either London Clay, Gault, or Oxford Clay. How might you determine its geological age? (22.)

30. Draw a section showing igneous rocks:—1st as dykes, 2nd as intrusive sheets, and 3rd, as contemporaneous beds. (22.)

31. What are Joints in rocks? How have they been produced? Explain the origin of jointed structure. (22.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on p. 84.

You are permitted to attempt *all* the questions.

The value attached to each question is the same.

41. Describe Darwin's explanation of the origin and distribution of Coral Reefs. Sketch the recent history of opinion upon this question.

42. Describe the Tertiary volcanic rocks of Britain.

43. How does Calcite differ from Aragonite? Describe the part which each plays in the structure, formation and preservation of Molluscan shells.

44. Explain, by the aid of diagrams, how the "throw" of a fault may vary along the strike.

45. Describe some recent researches and discussions as to the origin of the Crystalline Schists. Illustrate your answer by reference to some special district.

46. Arrange the following Fossils in vertical columns, in order of their geological age, writing against each one the name of the formation of which it is characteristic, and the name of the sub-division in the Animal Kingdom to which it belongs:—Ammonites discus, A. Jason, A. margaritatus, A. varians, Ampyx nudus, Cardinia Listeri, Cyrena consobrina, C. cuneiformis, Fusus contrarius, Hippopodium ponderosum, Lima gigantea, Orthis calligramma, Phacops caudatus, Productus semireticulatus, Spirifer glabra, S. Walcotti, Terebratula obovata, Unio Valdensis.

SUBJECT XIII. MINERALOGY.

EXAMINER, F. RUTLEY, ESQ.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *six* questions in all, of which the last question (No. 10) is obligatory.

The value attached to each question is shown in brackets after the question.

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1. What is Iceland-spar? What are its optical properties? (14.)
2. How is a tetrahedron derived from an octahedron? Name three minerals which crystallize in one or other of these forms. (14.)
3. Name three minerals which crystallize in the monoclinic or oblique system, and state the number and relative positions of the axes in these crystals. (14.)
4. Give the chemical composition of the following minerals:—
   Blende, gypsum, chalybite, ruby, graphite, and cerussite.
5. Describe three sulphides from which silver, copper, and antimony are respectively procured. (14.)
6. What is orpiment? By what tests would you recognise it? (14.)
7. To what useful purposes are the following minerals applied:— Orthoclase, emery, muscovite, cinnabar, kaolin, and asbestus? State what you know concerning the mode of occurrence of each of these minerals. (14.)
8. What are the characters by which you would distinguish apatite from beryl and from pyromorphite? (14.)

9. Define the terms reniform, stalactitic, pisolitic, and dendritic. (14.)

10. Name the three specimens placed before you, giving the systems in which they respectively crystallize and the chemical composition of each. Also make a blowpipe analysis of the three powdered minerals given you, stating briefly, but clearly, your results and the means by which you have arrived at them. (30.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions in all, of which the last two (Nos. 29 and 30) are obligatory.

The value attached to each question is shown in brackets after the question.

21. State what you know concerning the mode of occurrence and the crystallisation of sulphur. Draw a crystal of native sulphur, marking the faces with Miller's or Naumann's symbols. (14.)

22. Name any minerals which are isomorphous with magnetite, and state their chemical composition. (14.)

23. In what respects does a positive differ from a negative uniaxial crystal? (14.)

24. Describe the minerals pyrargyrite and stannine. (14.)

25. In what systems do the following minerals crystallise: Anthophyllite, copper-uranite, borax, celestine, nitre, and mispickel? (14.)

26. How would you distinguish anglesite from cerussite, cerussite from aragonite, and aragonite from calcite? (14.)

27. Describe the construction and use of a dichroscope. (14.)

28. Give a short account of the principal ores of zinc. (14.)

29. Describe the six models placed before you, naming a mineral which crystallises in each of these forms. (14.)

30. Name the three specimens placed before you, giving the chemical composition and crystallographic system of each. Make, also, a blowpipe analysis of the three powdered minerals supplied to you, briefly but clearly describing your mode of procedure and the results arrived at. (30.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions in all, of which the last (No. 48) is obligatory.

The value attached to each question is shown in brackets after the question.

41. In what systems do the following minerals crystallise: Liévrite, wulfenite, hemimorphite, leucite, barytocalcite and native bismuth? (14.)

42. By what tests would you distinguish the axes of maximum, mean, and minimum optical elasticity from one another in a biaxial crystal? (14.)

43. Describe the phenomena presented in convergent polarised light by a section of any biaxial crystal when cut at right angles to one of the optic axes. (14.)

44. Draw two scalenohedra of calcite, one being twinned upon the basal plane and the other upon the face of the rhombohedron 2 R. (14.)

45. Describe the minerals stibnite and jamesonite. (14.)

46. Give an account of the effects produced by percussion and pressure upon rock-salt, calcite, muscovite, and biotite. (14.)

47. Draw a crystal of sphene, marking the faces with Miller's symbols. (14.)

48. Name the six specimens placed before you, giving the chemical composition of each, and the system in which it crystallises. Also make a complete qualitative blowpipe analysis of the three powdered minerals set before you, describing the results of your analysis and the means by which you have arrived at those results. (30.)

SUBJECT XIV. ANIMAL PHYSIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR M. FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

1. What structures form the roof, the front wall, and the back wall of the cavity of the abdomen? Mention the most important organs which lie in the cavity of the abdomen, and describe as accurately as you can the general form and position of each of these important organs. (16.)

2. State the exact place in the aorta and in the pulmonary artery where valves are found. Describe the form of these valves, and their nature (as far as can be ascertained without a microscope). Explain exactly what happens to them during and after a contraction of the ventricles. (16.)

3. How does the blood in the pulmonary veins differ from the blood in the pulmonary artery? How is that difference brought about? Under certain circumstances the blood in these vessels may be almost exactly alike: What are these circumstances? (16.)

4. Give an account of any one of the ribs, say the fifth or sixth, describing its form, and stating how it is connected to other parts of the body. In what ways can it be moved by muscles, and what muscles can move it? (16.)

5. What is meant by a food-stuff? What are the three chief classes of food-stuffs, and how do they differ from each other? Give examples. (9.)

6. How are spinal nerves joined on to the spinal cord? What is the evidence that the two roots have different uses? (9.)

7. What is the portal vein? Where does it begin? Where does it end? Is the blood flowing in the portal vein always of the same quality, or does it vary? If so, when and how? (9.)

8. What is cartilage, and how does it differ from bone? State, as fully as you can, all the places in a grown-up body in which cartilage is found. (9.)

9. What does a nerve look like when seen with the naked eye? What is shown by the microscope to be its structure? What is going on in the nerves of the arm when we move the arm? (9.)

10. What is meant by the clotting of blood, and what changes take place in blood when it clots? What other fluids in the body, besides blood, clot like blood? (9.)

11. With what part of the nose do we smell? What is the nerve by which we smell? From what part of the brain does it start, and how does it reach the nose? Why does closing the nostrils do away with certain so-called tastes? (9.)

12. What is perspiration, and how is it produced? What is meant by "sensible" and "insensible" perspiration? (9.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

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21. Give an account of the position, attachments, and structure of the diaphragm. State the origin, course, manner of ending, and function of the nerves which are distributed to it. Describe the movements of the diaphragm, and explain exactly how these movements lead to the entrance of air into, and exit from, the chest. What is hiccough? In what acts, other than respiration, does the diaphragm take part? (26.)

22. What do you understand by arterial blood pressure? Explain the part which arterial blood pressure plays in the circulation of the blood, pointing out the causes which lead to the establishment of a mean arterial blood pressure, or to a rise or to a fall of pressure? What are the chief results of a rise or fall of pressure? About how much is the mean arterial pressure in a large artery in a large animal, for instance, the carotid of a dog? (26.)

23. Describe the structure of a salivary gland, and the nature and properties of saliva. Trace out the chain of events by which a flow of saliva follows upon food being placed in the mouth, including an account of the changes taking place in the gland itself. (16.)

24. Describe the structure of a red corpuscle, and give an account of the properties of Hæmoglobin, and of the uses of the red corpuscles in the body. (16.)

25. Describe the course of a spinal nerve within the spinal canal, and its manner of attachment to the spinal cord, as far as can be made out with the naked eye, or with a simple lens. Add what further facts can be learnt by the help of the microscope. Describe the structure, and state what is known concerning the functions of the ganglion on the posterior root. (16.)

26. Give an account of the structure of the liver, dwelling especially on the minute structure of a lobule. What is glycogen? How does it differ from sugar (grape sugar, glucose, dextrose)? What is the evidence that the liver forms glycogen? (16.)

27. State the nature of perspiration, distinguishing between sensible and insensible perspiration. Describe the structure of the organs which secrete perspiration, and explain why profuse perspiration takes place (1) when the body is exposed to warmth; (2) as the result of strong emotions; (3) as the result of dyspnœa. (16.)

28. Give an account of the structure of the retina, including the "pigment" or "retinal" epithelium. How does the macula lutea differ from the rest of the retina, and how do we know that the processes of vision begin in the region of the rods and cones?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

The value attached to each question is the same.

41. Describe the structure, and give a general account of the distribution of non-medullated nerve-fibres; discuss the function of these fibres, and their relations to the central nervous system.

42. Give an account of the chemical nature and physiological properties of the products of the gastric and pancreatic digestion of proteids, with special reference to the light thus thrown on the nature of proteids.

43. State and criticise the more prominent theories concerning colour vision.

44. Describe the changes, known as those of "degeneration," which follow upon injuries to nerve fibres. State and discuss the conclusions which have been drawn from the appearance of "degenerating" fibres, after injuries to parts of the central nervous system, or to nerves.

45. State what is known concerning the nature of the act of secretion of urine by the kidneys, explaining, as far as you are able, the several ways in which various influences may increase or decrease the flow of urine.

46. Discuss the seat, and mode of origin, of the nervous impulses of respiration, dwelling especially on the nature of the nervous mechanism by which respiration is variously modified.

Practical Examination.

1. State the important histological features of any *two* of the preparations *A, B, C*.
2. State the nature of any *two* of the tissues *a, b, c*. Give your reasons, and leave for the inspection of the Examiners the preparations on which your conclusions are based.
3. Two substances of physiological importance are present in the fluid *I.*, and one in the fluid *II.* What are they?
4. Demonstrate experimentally the nature of tetanus.

SUBJECT XV. BOTANY.

EXAMINERS, S. H. VINES, ESQ., M.A., D.Sc., F.R.S., AND
D. H. SCOTT, ESQ., M.A., PH.D.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced stages is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *six* questions.

You must attempt the first question on the paper. The remaining five you may select from any part of the paper.

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1. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

   Stem.
   Leaves.
   Inflorescence.
   Bracts.
   Flower.
   Calyx.
   Corolla.
   Stamens.
   Pistil.
   Fruit.
   Seed.
   (25.)

2. Describe the peculiarities of form and structure which are characteristic of the root. (15.)
3. Describe the structure of a grain of wheat, and the mode of its germination. (15.)
4. State what are the functions of a foliage-leaf, and explain how the structure of the leaf is adapted to the performance of these functions. (15.)
5. State what is the essential difference between *definite* and *indefinite* inflorescences, describing, with examples, the principal varieties of each. (15.)
6. Describe the process by which, after the pollen-grains have reached the stigma, the fertilization of the ovules is effected. (15.)
7. Explain the effect of (a) *cohesion*, (b) *adhesion*, and (c) *suppression*, in modifying the structure of the flower, illustrating your answer by reference to the Leguminosæ, Compositæ, and Labiatæ. (15.)
8. Describe the structure of a leaf-bud, such as may be found on a tree in winter. Mention instances of underground buds. (15.)
9. Give an account of the Respiration of plants, and describe an experiment demonstrating it. (15.)
10. Explain the structure, as seen in transverse section, of a twig of any Dicotyledonous tree. (15.)
11. Describe the following forms of fruit: legume, siliqua, drupe, and berry, giving examples of each. (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *six* questions.

You must attempt the *first* question on the paper, the remaining *five* you may select from any part of the paper.

21. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem.	Flower.	Pistil.
Leaves.	Calyx.	Fruit.
Inflorescence.	Corolla.	Seed.
Bracts.	Stamens.	

(25.)

22. Describe fully the structure of the female inflorescence and flower of *either* the oak or the beech. (15.)

23. Describe and explain the formation of starch in the cells of organs which are not exposed to light. (15.)

24. Describe generally the structure of bast-tissue, and state what are the functions of the various constituents of this tissue. (15.)

25. Describe the origin and development of a foliage-leaf. (15.)

26. Explain the mode of lateral branching of the root. What is the characteristic difference between Vascular Cryptogams and Phanerogams, as regards the lateral branching of the root? (15.)

27. Describe fully the structure of the ovule in Pinus at the time of fertilization. (15.)

28. Give a comparative account of the structure of the fruit in the British genera of Rosaceæ. (15.)

29. Describe the development of periderm in the stem. In what respects do cork-cells differ from ordinary parenchymatous cells? (15.)

30. Give an account of the influence of Light and Gravity upon the direction of growth of stems and roots. (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

You must attempt the *first* question on the paper, the remaining *four* you may select from any part of the paper.

The value attached to each question is the same.

41. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem.	Flower.	Pistil.
Leaves.	Calyx.	Fruit.
Inflorescence.	Corolla.	Seed.
Bracts.	Stamens.	

42. State the nature of the evidence on which stamens are considered to be homologous with foliage-leaves. Give instances of flowers in which the pollen-sacs are borne, not upon leaves, but upon the axis of the flower.

43. Describe and explain the experiments by which Knight investigated Geotropism.

44. Give a full account of the development of the embryo-Fern. Explain the function of the "foot."

45. Give an account of the chief histological peculiarities of the leaves of the Coniferæ.

46. Give an account of the development of the ovule and of the embryo-sac in any Angiosperm. Explain the grounds on which the ovule is regarded as a macrosporangium.

47. Give an account of the phenomena of apospory and apogamy, as observed in Ferns.

48. Give an account of the origin and characteristics of Alpine Floras.

Practical Examination.

I.

1. Make preparations to show any two stages in the development of the *embryo* in specimen 1.
2. Make a preparation to show the histological changes preceding the *fall of the leaf*, in specimen 2.
3. Make a preparation to show a *water-gland* in longitudinal section, in specimen 3.

Each preparation must be mounted in glycerine, glycerine jelly, or Canada balsam; it must be properly labelled, and accompanied by a *description* and *drawing*.

II.

1. Identify and shortly describe the four museum specimens marked A—D.
2. Identify and shortly describe the four microscopical specimens marked 1—4. These preparations must *not* be shifted.

SUBJECTS XVI. AND XVII. GENERAL BIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR MICHAEL FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Elementary paper;

Or from the Advanced paper in Animal Morphology and Physiology;

Or from the Advanced paper in Vegetable Morphology and Physiology;

Or from the Honours paper in Animal Morphology and Physiology;

Or from the Honours paper in Vegetable Morphology and Physiology;

But you must confine yourself to one of them.

Where the values differ, that attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will, in all cases, secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in these subjects lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

1. Describe the structure of a leaf, pointing out the uses of several parts. If in early summer you were to strip off all the leaves from a gooseberry bush or apple tree, what would happen, and why? (16.)
2. Describe the appearances presented by an Amœba, and explain as exactly as you can how it moves and how it eats. How does a Hydra differ from an Amœba? (16.)
3. What is the structure of a root of a plant? How does a root differ from a stem? What goes on in a root when a plant is living and growing, and how is the structure of the root adapted for the purpose? (16.)

4. Describe the appearance and properties of the blood of a crayfish or lobster, and compare it with the blood of a frog. Describe also the manner in which the blood circulates in a crayfish or lobster, and compare the circulation in a crayfish or lobster with the circulation in a frog. (16.)

5. A piece of bread put into a cupboard apparently empty becomes in a few days covered with mould: What is the nature of that mould? Why did it come on the bread, though previously there was apparently no mould in the cupboard? (9.)

6. Explain exactly how a mussel breathes. What would happen if you kept a mussel in water which had been thoroughly boiled (but allowed to cool), and why? (9.)

7. What is the general structure of a fruit, giving some instances? Explain what part of the flower grows into the fruit, and how the growth takes place. (9.)

8. A pond or an aquarium in which in winter not a single Hydra (fresh water polype) could be seen, may in spring appear crowded with them. Explain how this is brought about. (9.)

9. The rhizome of a fern may grow longer and so may the branch of a tree. Is there a difference in the way these two things grow longer, if so, what is that difference? (9.)

10. Where in the body of a frog is the central nervous system placed? How is it protected? What is its general appearance as seen during a dissection? What are its most important parts? (9.)

11. What is meant by the "germination" of a seed? Describe the state of things in some seed before germination, and the changes taking place during germination. (9.)

12. What is the general structure of the eye of a crayfish or lobster? What conclusions can you draw from the structure of the eye as to the kind of sight which a crayfish possesses?

SUBJECT XVI. ANIMAL MORPHOLOGY AND PHYSIOLOGY.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

21. Describe and compare in the cod, the frog, a bird, and a mammal, the heart and the manner in which the dorsal aorta is connected with it.

22. Trace the development of the central nervous system of the chick until the end of the third day of incubation. State what you know about the development of the spinal nerves.

23. Give a short account of the anatomy of the whelk. Compare its nervous system, renal organs, and heart with those of *Anodon*.

24. State the most important characters of the group Insecta. Describe and compare the mouth-parts and life-history of a black-beetle (cockroach) and a butterfly.

25. Describe the skeleton of the pectoral fins of the dog-fish, and of the fore-limbs of the porpoise.

26. Describe the organisation of any Radiolarian. State what you know concerning the functions of the various parts, and give a short account of the classification of the group.

27. Give an account of the anatomy of the fluke, and trace briefly the history of its development.

28. Describe the structure of a sponge. Explain the functions of the various parts mentioned.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

The value attached to each question is the same.

41. Describe the structure of an Actinozoon polyp. Give a short account of the skeletal structure of the *Actinozoa*. Give an account of the various theories which have been put forth respecting the origin of coral reefs.

42. Give a concise account of the anatomy of *Amphioxus*. Point out fully the important points of difference between it and the higher vertebrata, and of resemblance between it and some invertebrata.

43. Describe the water-vascular system of a typical Echinoderm. Point out the principal modifications presented by this system in other Echinoderm groups. State what you know of its development in any particular case.

44. Describe and compare the cleavage of the egg, and the formation of the embryonic layers in a frog, a bird, and a mammal.

45. Give a short account of the structure and life-history of a barnacle.
Describe the structure of a typical *Nauplius* and *Zoœa* larva, and state the groups of Crustacea in which they are found.

46. What is the systematic position of the following genera:—*Phyllosoma, Echinoderes, Trochosphæra, Clio, Pauropus, Hectocotylus, Pyrosoma, Phoronis, Loxosoma?* Give your reasons for the place which you assign to each.

SUBJECT XVII. VEGETABLE MORPHOLOGY AND PHYSIOLOGY.

EXAMINERS, S. H. VINES, ESQ., M.A., D.Sc., F.R.S., AND D. H. SCOTT, ESQ., M.A., PH.D.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

The value attached to each question is the same.

51. State what is the chemical nature of the alcoholic fermentation excited by the Yeast-plant (Torula), and explain the physiological importance of this process to the Yeast.
52. Give an account of the process of conjugation, as it occurs in Spirogyra, Closterium, and Mucor.
53. Give a comparative account of the structure and arrangement of the vascular bundles in Selaginella, Lycopodium, and Equisetum.
54. Indicate, by reference to Marchantia and to Polytrichum, what are the most important differences between Liverworts and Mosses.
55. Give an account of the adaptations for ensuring cross-fertilization which are presented by the flower of Lythrum.
56. Give an account of the process of sexual reproduction in Polysiphonia, or any other member of the Florideæ.
57. Give an account of the structure of the fructification of Agaricus, including the development of the spores.
58. Compare the life-history of Pinus with that of Pilularia, pointing out the homologies of the various reproductive organs of the two plants.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

The value attached to each question is the same.

61. Describe and fully explain the daily period of growth as graphically expressed by a curve.
62. Compare the processes of germination of the macrospore in Pinus and in Ranunculus, and fully explain what is the important difference between the two cases.

63. Give an account of the present state of knowledge as to the mode of growth in thickness of the cell-wall.

64. Describe the structure of the fully-developed sporogonium of any Moss, and explain in detail how the nutrition of the sporogonium is carried on.

65. Give an account of the development of the embryo in Selaginella, pointing out the features in which it resembles that of other Vascular Cryptogams on the one hand and that of the Phanerogams on the other.

66. Enumerate the groups of plants in which ciliated antherozoids (spermatozoids) are developed. Give an explanation of the absence of ciliated antherozoids in Phanerogams.

SUBJECT XVIII. PRINCIPLES OF MINING.

EXAMINER, H. BAUERMAN, ESQ., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *seven* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

1. What is a lode or mineral vein?
2. What minerals are usually found in stratified deposits?
3. Define the terms, fault, throw, hitch and heave, as used by miners.
4. Describe two kinds of picks used in coal and metal mining, giving figures and dimensions.
5. How is timber used for securing levels or drifts underground? Give examples of two methods.

6. Describe the operations of sinking a shaft and securing it with brickwork.
7. What is the pillar and stall system of coal working?
8. How are gunpowder and dynamite used in mining?
9. What kinds of ropes are used for drawing in mines?
10. Describe a furnace used for ventilation underground.
11. What is hematite, and where is it principally found?
12. What minerals are contained in tin stuff, and how is black tin produced from it?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *seven* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

21. What are true veins, segregated veins, and contact deposits? Give an example of each.
22. What kinds of coal are found in the Carboniferous strata of Great Britain, and how do they differ from each other?
23. What is a gozzan, and what kinds of minerals are usually found in it? Give examples from silver, copper, and lead-ore lodes.
24. When a lode is heaved by a cross course, in what direction would you drive to recover it?
25. How is a coal field, containing a large number of seams with a high dip, laid out for working?
26. What are the relative merits of vertical and inclined shafts for working mineral veins?
27. Describe a boring-machine and appliances suitable for driving or sinking in hard ground.
28. Describe the method of endless rope-hauling in two modifications.
29. Describe two methods of long-wall working suited for flat and inclined seams respectively.
30. Describe the Mueseler safety-lamp, both in the plain and shielded forms.
31. Describe the anemometer and water-gauge, and show how they are applied to determine the efficiency of ventilation.
32. Describe some machines for saving ores from fine slimes, working continuously.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

41. Give an account of the Northumberland and Durham coal-fields, including the lower Carboniferous districts.
42. What are the most important copper-producing districts at the present time? Describe one or two of them in some detail.
43. What methods have been proposed for driving, sinking, and getting minerals in mines without the use of explosives?
44. What is the effect of coal-dust on the atmosphere of fiery mines, and what special precautions are required in working such mines?
45. Describe and illustrate the method of dividing a circular shaft into compartments for drawing, pumping, and footways, or a rectangular shaft giving similar accommodation.
46. It is required to raise 250 gallons of water per minute from a mine 350 yards deep. Give a general idea of the plant that you would prefer for the work.
47. How is coal cleaned from shales, &c., before coking?
48. Describe the principal kinds of stamping-mills used for crushing minerals.

SUBJECT XIX. METALLURGY.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question and of the section before your answer.

You are to confine your answers *strictly* to the questions proposed; answers extending beyond the scope of the questions are disregarded by the Examiner.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not to attempt more than *six* questions in this paper.

The value attached to each question is the same.

For a pass in the Elementary stage the student will only be expected to answer questions in *two* of the following *four* sections. At least two questions must, however, be taken from Section I.

For a FIRST CLASS in the Elementary stage the candidate must answer questions in at least *three* sections. At least two questions must be taken from Section I.

SECTION I.

1. Distinguish between the terms "kiln," "blast furnace," and "reverberatory furnace," and state what are their respective uses.
2. In what way does anthracite differ from Newcastle or house coal?
3. Describe how you would prepare wood-charcoal by any ordinary method.
4. Arrange the following metals in the order in which they melt:—Copper, lead, iron, tin, gold, zinc, and silver.

SECTION II.

5. How do you account for the fact that iron pyrites is not, at the present time, useful as an iron ore?
6. Describe accurately how you would weld two pieces of wrought-iron, and state how you would harden a strip of steel. Give the reasons for the course you adopt in each case.
7. How would you smelt an iron ore in order to produce "pig iron"? Give a sketch of the furnace you would use.
8. Describe one method of converting "pig iron" into steel.

SECTION III.

9. What is the action, at a bright red heat, of air on silver sulphide.
10. A silver ore has been roasted with salt, and the silver in the roasted material is present as chloride. How would you extract the chloride and precipitate the silver in the metallic state?
11. How would you extract gold from the amalgam obtained in the treatment of gold quartz?
12. What is the action of chlorine gas on molten gold containing silver?

SECTION IV.

13. Describe the process of refining copper, and state what is the action of cuprous oxide in this process.

14. State how you would smelt tin stone (SnO_2) with a view to extract the tin it contains.

15. What is "red lead," and how is it prepared?

17. State which is the chief ore of mercury, and describe how mercury is extracted from it.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to attempt more than *six* questions in this paper.

The value attached to each question is the same, except No. 24, of which the value is twice the value of each of the other questions.

For a pass in this stage the student will only be expected to answer questions in *two* of the following *four* sections; at least *two* questions must, however, be taken from Section I.

For a FIRST CLASS in this stage the candidate must answer questions in at least *three* sections; at least *two* questions must be taken from Section I.

SECTION I.

21. How would you test a clay crucible in order to ascertain whether it was suitable for ordinary laboratory use?

22. On analysing two samples of clay it is found that one of them contains 4 per cent. of potash and soda, while these substances are absent in the other. How would these clays behave at high temperatures?

23. State the conditions under which you would employ (1) basic bricks and (2) acid bricks in the construction or lining of metallurgical furnaces.

24. Name the six specimens submitted to you.

SECTION II.

25. How do you account for the fact that pig iron produced with coke as a fuel and with hot blast is of different character to pig iron produced by the aid of charcoal and with cold blast?

26. What is a "chill casting," how is it produced, and to what cause do you consider the change in the character of the metal to be due?

27. What is the composition of the slag produced (1) in the blast furnace during the smelting of iron ores and (2) during the smelting of manganiferous ores for the production of Spiegeleisen?

28. Give a sketch in vertical section of the ordinary "pipe stove" used for heating blast.

SECTION III.

29. Describe the pan amalgamation of silver ores, and give a sketch of the appliance used.

30. How is silver separated, in the wet way, from a solution which mainly consists of chloride of copper?

31. Gold containing small quantities of lead, antimony, and tin is too brittle to roll; state how you would remove these impurities.

32. Under what circumstances would you extract gold from an ore by the aid of (1) lead and (2) mercury?

SECTION IV.

33. If a small quantity of arsenic is present in metallic copper, how will the physical properties of the copper be affected?

34. What happens when a mixture of the sulphides of iron, of copper, and of silver is submitted to a gradual increase of temperature in the oxidizing atmosphere of a reverberatory furnace?

35. How does the Welsh method of treating copper ores in reverberatory furnaces differ in principle from the blast furnace method?

36. Show by the aid of a sketch in sectional elevation the arrangement of a furnace with a water-jacket, as used in the smelting of lead ores.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to attempt more than *eight* questions, and in these No. 51 must be included.

The value attached to each question is the same.

40. Show by sketches in plan and vertical section *either* Hoffmann's circular kiln, as used for burning fire-bricks, *or* Lürmann's kiln, used for the continuous coking of coal.

41. How do you account for the passage of silicon into pig iron in the blast furnace treatment of iron ores? How would you proceed in order to obtain a pig iron rich in silicon?

42. Show by the aid of a sketch the arrangement of the Clapp-Griffith modification of the Bessemer convertor. State what advantages are claimed for the process, and describe the character of the metal produced.

43. In the desilverization of lead by zinc some of the zinc remains dissolved in the lead. How does this influence the quality of the lead, and how may the zinc be eliminated from the lead?

44. An ore contains both the sulphide and the sulph-arsenide of silver. How would you treat it?

45. What are the relative advantages and disadvantages of Cornish rolls and of stamps in the crushing of auriferous quartz?

46. How would you separate, by a "wet" method, the iron, copper, nickel, and cobalt present in a speise?

47. Metallic bismuth is found to contain gold; how would you extract the latter metal?

48. In refining copper, lead is sometimes added to the molten bath; why is this done, and under what circumstances should it not be added?

49. Two slags have to be treated, one containing lead and the other copper; what methods would you employ in order to extract these metals?

50. Impure lead and pure copper are separately melted, and the molten metals are each allowed to stand for some time in an oxidizing atmosphere. How would this treatment affect the properties of the metals after they have solidified?

51. Name and describe briefly the six specimens submitted to you.

SUBJECT XIX*p*. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Elementary Stage.

Three hours are allowed for this examination.

1. The candidate is required to form sulphide of tin from the tin and sulphur given to him. He is to deduce the chemical composition of the product from the increase in weight of the tin.

2. The candidate is required to melt the sample of copper given to him, and to produce by oxidizing it and by "poling" it, "dry," "tough," and "overpoled" copper.

Note.—The candidate must place the number of his examination paper on the products he obtains, and hand them to the Superintendents of the examination, to be returned to the Department for examination.

SUBJECT XIX*p*. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Advanced Stage.

Four hours are allowed for this examination.

1. The candidate is required to prepare "Speculum metal" from the tin and copper given to him. He is to calculate the composition of the alloy he produces from its weight.
2. The sample is an ore of antimony. The candidate is required to describe it, and to determine the percentage of metal by a "dry" or by a "wet" method.

Note.—The candidate must place the number of his examination paper on the product he obtains in the *first question*, and hand it to the Superintendents of the examination, to be returned to the Department for examination.

Honours.

Eight hours are allowed for this examination.

1. The sample of regulus sent contains iron and copper. The candidate is required to roast this so as to produce sulphates of the two metals. The roasted product is then to be treated with water, and the percentages of iron, copper, and sulphuric acid present in the solution are to be determined.
2. The candidate is required to determine the percentages of lead and of iron in the sample of impure zinc given him. He is also to test the zinc for the presence of arsenic.

Note.—None of the products are to be returned.

SUBJECT XX. NAVIGATION.

EXAMINER, REV. J. B. HARBORD, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

In all cases the number of the question must be placed before the answer on the worked paper.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *eight* questions, viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Define equator, first meridian, poles of the earth, latitude, longitude; distinguish between great and small circles on the surface of the earth, and give an example of each. What is a degree? (12½.)

2. Define difference of latitude, difference of longitude, course, distance. Required the difference of latitude and the difference of longitude between A and B—lat. A 30° 10′ N., long. A 5° 15′ E.; lat. B 10° 20′ N., long B 10° 29′ W. On what curve is the nautical distance always reckoned, and on what curve is the shortest distance? (12½.)

3. Draw a compass card. How many degrees are there between S.S.E. and S.W.¼W.? A ship's head is 42° 11′ 15″ to the west of north; describe this by the point of the compass. Define variation, deviation, leeway. (12½.)

4. What do you mean when you speak of plane sailing? What do you understand by resolving a traverse? Prove the formula, diff. long. = dist. × sin. course × sec. mid. lat. (12½.)

5. Describe fully the common log, with all that is necessary in connexion with it when used. Describe the process of heaving it, and mention the precautions for ensuring a correct result. (12½.)

6. When a ship's head swings round, how is it that the compass card remains stationary, and what indicates the direction of the ship's head? To what causes is the deflection of the compass needle on board ship, from the geographical meridian, due? How can you find out how much is due to one cause and how much to another? (12½.)

Section II.

7. A ship sails due east, from a place in latitude 50° 10′ N. and longitude 32° 30′ W.; find the latitude in and longitude in. (7.)

8. A ship sails 263 miles N.W. by N., and then finds her latitude to be 28° 20′ S.; what was the latitude of the place she sailed from? (9.)

9. What is the distance of St. Helena (lat. 15° 55′ S., long. 5° 43′ W.) from a ship in lat. 18° 10′ S. and long. 8° 30′ E., and on what true course must she sail to arrive there. (10.)

10. Find, by middle latitude sailing, the latitude in and longitude in, the ship having sailed 245 miles due east by compass from a place in lat. 30° 20′ S. and long. 55° 10′ E.; variation 2¼ points W., deviation 8° 30′ W. (13.)

11. Find the compass course and distance from St. Abb's Head (lat. 55° 55′ N., long. 2° 8′ W.) to the Naze (lat. 57° 58′ N., long. 7° 3′ E.); variation 2¼ points W., deviation 11° E. (13.)

12. A ship leaves Cape St. Vincent (lat. 37° 3′ N., long. 9° W.) and sails as follows:—

True Courses.	Distances.
W.	88 miles.
N.W.	20 ,,
E.S.E.	52 ,,
S.	65 ,,
N.E. by N.	16 ,,

Find the latitude in and longitude in. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt all or any of the questions.

21. Explain what you mean by Mercator sailing. Apply the method to find the compass course and distance from Cape Clear (lat. 51° 25′ N., long. 9° 29′ W.) to Funchal (lat. 32° 47′ N., long. 16° 58′ W.); variation 28° W., deviation 7° W. (20.)

22. A ship, in the southern hemisphere, changes her longitude 15° without altering her latitude, sailing a distance of 540 miles. What is her latitude?

    Prove the formula you use, drawing a diagram. (20.)

23. Under what circumstances can middle-latitude sailing be used with advantage? When should the use of this formula be avoided? Give examples of each.

    A ship in the southern hemisphere sails a distance equal to the difference of longitude on a course S. 30° W. Find the middle latitude. (20.)

24. A ship is distant from her port 66 miles, and its bearing is N.E. by N.; after sailing in this direction for six hours at the rate of 8 knots the port bore E.S.E., and was 22 miles distant. Find the direction and rate of the current. (20.)

25. Describe Walker's Patent Harpoon Ship Log, drawing a figure and indicating clearly the use of the different parts. Define a nautical mile, and state how its length is obtained.

    A ship uses a glass which runs out in 28ˢ and a log line on which the length of the knot is 50ᶠ; after having made good 200 miles thus estimated, what will be the error in her distance? (25.)

26. Find the distance on the great circle between Port Egmont (lat. 51° 24′ S., long. 59° 56′ W.) and Simon's Town (lat. 34° 12′ S., long. 18° 26′ E.), and the initial course.

    What modification is necessary to render great circle sailing practicable? (30.)

27. Omitting the effect of horizontal soft iron on the compass of an iron ship, and supposing the deviation to be 3° E. when her head is north, 3° W. when it is N. by E., and that it continues to the westerly as her head passes through E. to S. by W., and then becomes easterly—what do you deduce from this as to the position of the ship when building? Explain clearly and fully the reason of your answer, with diagram. (25.)

28. January 29th, 1888, at noon, C. Recif (lat. 34° 1′ S., long. 25° 40′ E.) bore by compass north (ship's head being E.S.E.), distant 15 miles; afterwards sailed as by following log account. Required the latitude in and longitude in on January 30th at noon; variation 30° W. (40.)

H.	K.	$\frac{1}{10}$ths.	Courses.	Wind.	Leeway Points.	Remarks.
1	6	3	E.S.E.	N.E.	2	Deviation 13° 5′ E.
2	5	6				
3	4	9				
4	8	0				
5	8	6				
6	7	4				
7	4	6				
8	4	5	South.	N.N.E.	0	Deviation 3° 10′ E.
9	7	6				
10	8	7				
11	8	8				
12	5	0				
1	4	3	S.E.	E.N.E.	1½	Deviation 14° 10′ E.
2	3	8				
3	8	5				
4	4	4				
5	5	2				
6	6	8				
7	5	4	N. by W.	S.W.	½	Deviation 9° 15′ W.
8	7	5				
9	9	0				
10	6	3				
11	8	4	N.W.	W.S.W.	1	Deviation 22° 0′ W.
12	5	3				

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper. You are permitted to attempt all or any of the questions.

41. From the top of a cliff, 598 feet above the surface of the sea, the angle of depression of a ship, bearing south, is found to be 45°, and that of another ship bearing S. 30° W. is found to be 30°; find the distance of the two ships from each other. (40.)

42. A ship sailing N. by E. by compass, 8 miles an hour (variation 2½ points W., deviation 11° E.), observes two peaks, A and B; A bears E. by S., and B bears E.N.E. by compass; an hour afterwards the bearing of A is S.E. and the bearing of B is E. Required the true bearing and distance of A from B. (40.)

43. A ship sails on the arc of a great circle from a place A in lat. 25° 30′ S., long. 90° 20′ W., to a place B in lat. 30° 10′ N., long. 150° E. Find the latitude of the vertex, and the course on which she crosses the equator. Show that these two, in such cases, always bear a fixed relation to each other. (50.)

44. Construct a traverse table for distance, 54,693 to each point.

Define the "danger angle." Supposing a ship to sail on the arc of a semi-circle, of which the two forts A and B are the extremities of the diameter, would she be in danger of a shoal the danger angle of which subtended by A B is 110°? Illustrate your answer by a figure.

If A B = 54,693 feet, find by the above table her distance from A and B when her bearing from A is E.N.E. and N.E. by N., B being due E. of A. (50.)

45. Describe the course of the revolving storms of the North Atlantic and South Indian Oceans. If a ship is compelled to heave to in a cyclone, what tack should be selected? Show how she can determine what part of the storm she is in. Give the rule for the direction in which the wind veers. (40.)

46. Explain fully the causes of the heeling error. In what positions of the ship is the change in the deviation due to the heeling greatest and least? Show why. Define the heeling coefficient. A ship's head is S. by E., and she heels 8°, which causes a change in deviation of 15° 40′; what will be the change when the ship's head is S.E., and she heels 10° in the same direction? (50.)

47. What distinction in the buoys is there on the two sides of a channel at the entrance to a harbour? How do you speak of these two sides? Describe the Y-level and its adjustments. (40.)

48. Construct a Mercator's chart on a scale of 1·2 inch to a degree of longitude, extending from the first meridian to 4° E., and from the Arctic circle to 69° N.

A ship leaves a place, A, in lat. 67° 10′ N., long. 3° 15′ E., and sails as follows (variation 27° 10′ W.) :—

Compass Courses.	Deviation.	Distances.
W. by N. ¼ N.	13° 20′ E.	42
N.E. by E.	4° 30′ W.	90
W.S.W.	7° 40′ E.	50

Lay down the true courses and take off the latitude in and longitude in. Give the magnetic bearing of A from the ship in her last position. (90.)

SUBJECT XXI. NAUTICAL ASTRONOMY.

EXAMINER, REV. J. B. HARBORD, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

You are only permitted to attempt *eight* questions, viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Define equinoctial, vertical circles, azimuth, hour-circles, celestial latitude, obliquity of ecliptic. Give diagrams. (12½.)

2. Describe how you find the altitude of a body above the sea-horizon. Distinguish between the observed, the apparent, and the true altitudes; and state how the true is obtained from the observed. (12½.)

3. Prove the rule for finding the hour angle of the sun, having given his declination and altitude and the latitude of the place. Draw diagram for the case when the sun is to the west of the meridian, his declination south, and the latitude of the place north.

   What must you apply to this angle before you can compare it with the time shown by chronometer? (12½.)

4. Define amplitude, and prove the rule for finding the variation of the compass by amplitude of the sun. Whence do you obtain the several data for this problem? What instrument do you use in the observation? (12½.)

5. Explain the difference between civil and astronomical time. Express in both the date and time at which you commenced to work this paper. Explain what you mean by the Greenwich date, and why it is so important. What difference in longitude is equivalent to a difference in time of $10^h\ 14^m\ 30^s$? What is the difference in time between two places, A in longitude 5° 20′ 30″ E., and B in longitude 89° 10′ 20″ E.? (12½.)

6. Supposing there to be no index error, what is the actual length of the limb of a sextant between 0 and the index, when the angle between two objects measured is 86°? What is the index error of a sextant? Explain how to find it by observations of the sun. (12½.)

Section II.

7. May 12th, 1888, in longitude 150° W., the observed meridian altitude of the sun's L.L. was 39° 20′ 30″ (zenith south of the sun), the index correction was + 1′ 50″, and the height of the eye above the sea was 20 feet. Required the latitude. (8.)

8. At a certain place on the parallel of 38° 20′ N., the sun's centre was on the meridian at the same time that it was in the vernal equinoctial point: find the altitude of the L.L., taking the semi-diameter from the "Nautical Almanac." (8.)

9. January 20th, 1888, at $7^h\ 8^m$ A.M., mean time nearly, in latitude 38° 30′ N., and longitude 40° 20′ W., the sun rose by compass E. 39° 20′ S. Required the variation, the deviation being 6° 27′ E. (10.)

10. June 6th, 1888, at 6^h P.M., mean time nearly, in latitude 50° 40′ N., and longitude 100° W., when the sun bore by compass N. 91° 40′ W., the observed altitude of the sun's L.L. in artificial horizon was 36° 50′ 30″; index correction, + 2′ 50″. Required the variation. (12.)

11. February 8th, 1888, at 9^h A.M., mean time nearly, in latitude 38° 30′ N., and longitude by account 147° 20′ E., when a chronometer showed $10^h\ 45^m\ 13^s$, the observed altitude of the sun's U.L. was 22° 18′ 20″; index correction, 3′ 30″—, height of the eye 17 feet.

    On 28th January, at noon, the chronometer was slow on G.M.T. $40^m\ 10^s$, and its rate was $5{\cdot}5^s$ gaining. Required the longitude. (14.)

12. April 18th, 1888, at $8^h\ 50^m$ A.M., mean time nearly, in latitude 32° 22′ N., and longitude 64° 30′ W., when a chronometer showed $2^h\ 10^m\ 0^s$, the observed altitude of the sun's L.L., in artificial horizon, was 84° 45′ 30″; index correction, + 2′ 30″. Required the error of chronometer on G.M.T. (14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt *all* or any of the questions.

21. Given the hour-angle of a star, show how to find the ship's mean time. Explain by diagram, showing a star east of the meridian.

Greenwich, April 10th, 1888, when a sidereal clock showed $7^h\ 20^m\ 10^s$, a chronometer showed $6^h\ 50^m\ 20^s$. Required the error of the chronometer on G.M.T., the error of the sidereal clock being $3^m\ 25{\cdot}5^s$ fast. (25.)

22. Explain shortly, but clearly, how it is that the observation of a lunar distance with the altitudes of the bodies enables you to determine the longitude.

What principal governs the selection of the bodies used for lunar distances? Give, with their correct right ascensions and declinations, those within distance on 1st January 1888, at 8 P.M. (25.)

23. Explain the correction for dip. Investigate an expression for calculating a table for "Dip of the Sea Horizon"; and show that approximately the dip in minutes is equal to the square root of the height of the eye in feet. (25.)

24. Investigate a rule for finding the latitude by altitudes of two stars taken at the same instant.

If the altitudes of the two stars are taken at different times ho do you find the polar angle? Give the corrections necessary when great accuracy is required. (25.)

25. February 4th, 1888, at $5^h\ 35^m$ A.M., mean time nearly, in longitude 30° 45′ W., the observed meridian altitude of the moon's L.L. was 40° 30′ 20″, zenith north; index correction + 8′ 10″; height of the eye above the sea 18 feet. Required the latitude. (25.)

26. June 6th, 1888, at 6 P.M., mean time nearly, at a place on shore, in latitude 50° 40′ N., and longitude 100° W., when the sun bore by compass S. 88° 20′ W., a chronometer showed $12^h\ 38^m\ 39^s$, the error of chronometer on G.M.T. being $8^m\ 10^s$ fast. Find the variation of the compass. (25.)

27. May 5th, 1888, in longitude 25° 20′ W., at $9^h\ 30^m\ 10^s$, mean time, the altitude of the Pole Star was 39° 15′ 50″; index correction —3′ 40″; height of the eye 22 feet. Required the latitude.

At what times will the Pole Star pass the meridian of this place, on this day? At what distance from the pole? Show whether the altitude was taken nearer the upper or the lower transit. (25.)

28. January 7th, 1888, at 2^h 35 A.M., mean time nearly, in latitude 25° 45′ N., and longitude by account 131° 10′ E., when a chronometer showed $6^h\ 11^m\ 4^s$, the observed altitude of Sirius west of the meridian was 29° 15′ 40″; index correction, 2′ 50″ +; height of eye 18 feet.

On January 1st the chronometer was fast on Greenwich mean time $20^m\ 30^s$, and its daily rate was $5{\cdot}5^s$ gaining. Find the longitude. (25.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper. You are permitted to attempt *all* or any of the questions.

41. Investigate a formula for finding the latitude by altitudes near the meridian, using estimated latitude. What is the correction thus obtained called? Why is this method resorted to when the meridian altitude method is much simpler than any other? Show that the error in latitude of place is least when the azimuth of the body is least; also that this method of determining the latitude is most useful in high latitudes. (50.)

42. Distinguish between a Line of Position and a Line of Bearing. Explain clearly the principle of the method for determining the place of a ship by lines of position. What are the advantages of this method? How can one line of position only be sometimes utilised?

The compass bearing of the sun was S. 10° 43′ E., the deviation being 3° 10′ W., when two points, A and B on line of position of the ship, were computed to be:—lat. A. = 35° 10′ N., long. A = 59° 20′ W.; lat. B. = 35° 40′ N., long. B = 58° W. Find the variation. (60.)

43. What is the moon's equatorial horizontal parallax when her distance from the earth is exactly 60 times the earth's equatorial radius?

Find the moon's horizontal parallax for the latitude of Greenwich (51° 29′ N.), when the horizontal parallax, as given in the "Nautical Almanac," is 56′ 45″.

Also find, by calculation, the parallax in altitude in this case, when the apparent altitude of the moon's centre is 40° 30′, the refraction being 1′ 8″. (50.)

44. May 16th, 1888, at 4^h 15^m P.M., mean time nearly, in latitude 30° 20′ N., and longitude by account 78° 10′ W., the following lunar observation was taken:—

Obsd. Alt. Sun's L.L.	Obsd. Alt. Moon's L.L.	Obsd. Dist. N.L.
31° 58′ 0″	53° 29′ 30″	64° 49′ 30″
Ind. cor. 2′ 10″—	1′ 10″—	50″—

Height of eyes was 20 feet. Required the longitude. (70.)

45. Take from the "Nautical Almanac" the right ascension and declination of Altair on June 29th, 1888, and thence compute the longitude and latitude of the star. (40.)

46. Show how it happens that there is only one high tide on certain days which are indicated by —, in the table of "Nautical Almanac," pages 474, 475.

Mention and describe briefly the different methods of finding the time of high water, at a place, on any particular day.

In surveying a harbour, what tidal observations should be made? (50.)

47. Describe the method of comparing the chronometers when there are several, say three, on board. Give a specimen of a Chronometer Journal, and state the use of the "Second Difference" column. Mention the precautions necessary in connexion with the winding of the chronometers. (40.)

48. In a marine survey how are the latitude and longitude of the Observatory Station usually determined? What objection is there to finding both extremities of the base line by astronomical observations? Describe clearly how the direction of the base line is ascertained. (40.)

Practical Examination.

Candidates were examined in the use of the sextant, azimuth compass, and Mercator chart.

SUBJECT XXII. STEAM.

Examiner, PROFESSOR GOODEVE, M.A.

General Instructions.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than *five* questions.

The value attached to each question is shown in brackets after the question.

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1. A winding engine performs 188,156 units of work per minute, and has a cylinder 20½ inches in diameter, the stroke of the piston being 2 feet 10 inches and the number of strokes per minute being 15. What should be the mean pressure per square inch exerted by the steam on the piston, neglecting loss of work by resistances?

   (Take $\pi = \frac{22}{7}$.) (15.)

2. Sketch a vertical section through the cylinder and piston of Newcomen's pumping engine. Where was the cold water for condensation admitted? What was the object of the snifting valve, and where was it placed? How was the condensing water got rid of and prevented from returning into the cylinder? (15.)

3. How many units of heat are required for raising the temperature of 1 lb. of water from 60° F. to 212° F., and then converting it into steam at 212° F.? (15.)

4. What is the difference between a *single* and a *double* acting engine? For what kind of work are single-acting condensing engines commonly used? Why is it the practice to employ three separate valves for distributing the steam in such an engine when *one* valve, properly constructed, will suffice in a *double*-acting engine? Name the valves and mention the particular purpose for which each is required. (15.)

5. What is the meaning of the term "*lead*" as applied to a slide valve? Sketch in longitudinal section the steam ports and passages leading to the top and bottom of the cylinder, and place the valve in such a position that the lead is ¼ inch, the lap of the valve being 1 inch, marking dimensions. (15.)

6. Sketch and describe the method of keeping the piston-rod steam tight in the cylinder cover. (15.)

7. The initial pressure of steam is 45 lbs. above that of the atmosphere, and the atmospheric pressure is 15 lbs. per square inch; the steam expands five times; what is the final pressure? Set off the expansion curve in a diagram, and mark the position of the atmospheric line. (15.)

8. The lever of a safety valve is balanced and is 24 inches in length; the distance between the fulcrum and the end of the valve spindle is 3 inches, the diameter of the valve being 2½ inches. Find the weight to be put on the end of the lever in order that the steam may escape at a pressure of 50 lbs. per square inch, the weight of the valve being neglected. (Take $\pi = \frac{22}{7}$.) (15.)

9. Sketch a section through the air pump and condenser of a condensing engine; name the several valves and essential parts, and point out their uses. Show the construction of the valves. (20.)

10. Describe an ordinary double-beat valve, making such sketches as may be necessary for showing the construction of the valve and the principle on which it acts. (20.)

11. In designing locomotive boilers it is necessary to provide for a sufficiently large amount of heating surface and a sufficiently strong draught. Sketch a section through a locomotive boiler, describing the manner in which these two requisites are provided for. (20.)

12. Make a section through the cylinder and piston of an oscillating engine, showing the connection of the piston with the crank shaft. Show by a separate drawing the belts or steam passages which serve for the admission and exit of the steam. (25.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *five* questions.

The value attached to each question is shown in brackets after the question.

21. Define a unit of heat. A steam engine indicates 25 H.P., how many units of heat does it convert into useful work per minute? (25.)

22. In a marine engine fitted with a surface condenser, the steam reaches the condenser at a mean absolute pressure of 3 lbs. per square inch, and is condensed to water at 120° F. How many pounds of circulating water, which enters at 60° F. and is discharged at 100° F., will be required for every 1 lb. of steam condensed? (The temperature of steam at 3 lbs. pressure=142° F.) (30.)

23. The diameter of a cylinder of a non-condensing engine is 18 inches, the length of stroke is 2 feet 6 inches, the mean pressure of the steam is 20 lbs. on the square inch above the atmosphere. Find the number of revolutions per minute when the engine develops 27 H.P. (30.)

24. In a direct-acting horizontal engine, where the connecting rod works between guides, the connecting rod is five times as long as the crank, the pressure on the piston when the crank is vertical being 1,250 lbs.; find the thrust on the slide bar, neglecting friction, and indicate the direction in which it acts. Does the direction of the thrust change during any part of the revolution? (35.)

25. Make a diagram of the valve and ports of a locomotive engine with crank and eccentric circles, showing the positions of the crank, of the centre of the eccentric, and of the slide valve, when the crank is on its dead centre. (35.)

26. What is meant by the term "clearance"? Assuming that the clearance has been reduced to an equivalent length of the stroke of piston, which is 4 feet, and taking the case where steam is cut off at half stroke, the clearance being 3 inches, you are required to compare the pressure of the steam, when 3 feet of the stroke are made, with the pressure under the same circumstances if there were no clearance. (40.)

27. State the formula connecting the position of the balls in Watt's governor with the speed of revolution.

Assuming the expression for the constant force under which a body describes a given circle with a given uniform velocity, write out a proof of the formula which you have given. (35.)

28. Sketch and describe a steam regulator valve as applied to a locomotive boiler, and show that by means of it the steam may be admitted gradually to the cylinders. Sketch roughly the position of the valve in the boiler. (40.)

29. Describe, with a sketch, Bourdon's steam gauge, and explain the principle of its action. (35.)

30. A compound condensing engine, with cranks at right angles and an intermediate receiver, has cylinders of 14 and 24 inches diameter respectively, each with a stroke of 36 inches. Draw the indicator diagrams which you would expect to obtain from the cylinders supposing steam of 90 lbs. absolute pressure is admitted to the high pressure cylinder and is cut off at half stroke, the steam in the low pressure cylinder being cut off at $\frac{5}{8}$ stroke, and the condenser showing a back pressure of 4 lbs. absolute. Attach a scale of inches and pounds to your diagram. (40.)

31. Sketch and describe two methods by which the internal tubes of a Lancashire boiler are strengthened against collapse. Name the advantages claimed for the plans you select. (35.)

32. Sketch a longitudinal section through a Giffard's injector, showing clearly the manner in which the flow of steam and water is regulated. Explain the principle of its action, and account for the apparently paradoxical result. (45.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

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41. A boiler makes steam containing 10 per cent. of suspended moisture; 100 lbs. of feed water are introduced at 100° F., and are raised into steam at 320° F. (pressure of 90 lbs. to the square inch), how much water at 212° F. could be converted into saturated steam at 212° F. by the same consumption of fuel. (60.)

42. Prove the formula for the efficiency of a perfect heat engine working between certain fixed limits of temperature. Under what conditions would a perfect engine be capable of converting into work the whole of the heat existing in a substance. (70.)

43. Point out some of the principal theoretical and practical considerations which have caused engineers to adopt compound engines in place of employing expansion in a single cylinder. Account for the economy of fuel resulting from the use of triple expansion engines. (65.)

44. Describe a form of reversing gear for a slide valve where a single fixed eccentric replaces the double eccentric and link. Explain the manner in which the arrangement acts and how it becomes effective in reversing the engine. (70.)

45. A normal indicator diagram of an expansive engine being given, show the method of plotting out the curve of crank effort. How is the curve affected by taking into consideration the inertia of the reciprocating parts? (60.)

46. It is required to design expansion gear for an engine so as to obtain various grades of expansion while the engine is at work. What valve or valves and valve-gear will you employ for this purpose? Make full sketches to illustrate your answer. (70.)

47. In a steam engine the cut off takes place at ·7 of the stroke, the angle of lead is 6° 9′, the width of the steam port is $1\frac{1}{2}$ inches, and the steam port opens $\frac{17}{24}$ of its area. Find by Zeuner's diagram (neglecting obliquity) the travel of the slide, the angle of advance, the outside lap and the outside lead. What would be the amount of inside lap necessary to produce cushioning after $\frac{6}{7}$ of the stroke has been performed? (65.)

$$\cos 66^\circ\ 25' = \cdot 4$$
$$\cos 59^\circ\ 52' = \cdot 502.$$

SUBJECT XXIII. PHYSIOGRAPHY.

EXAMINERS, PROFESSOR JOHN W. JUDD, F.R.S., AND
PROFESSOR J. NORMAN LOCKYER, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

The value attached to each question is indicated by the numbers in brackets.

1. What is the binary compound which occurs in the greatest abundance in the earth's crust, and of what elements is it composed? What minerals consist of this substance, and with what other binary compounds is it found united? (15.)
2. What difference will be observed in the reading of a barometer if we carry it from the sea-level to the top of a mountain three and a half miles in height? Explain the cause of this difference. (15.)
3. Describe the apparent annual motion of the stars, due to the earth's revolution round the sun. (15.)
4. Define stress, impulse, momentum. (11.)
5. Describe two simple chemical experiments. (11.)
6. State the various forms of water. (11.)
7. Does the mariner's compass point due north? If not, why not? (11.)
8. Give a proof of the earth's rotation. (11.)
9. What are lavas? Of what chemical elements are lavas chiefly composed? (11.)

10. Explain the mechanical action of water, when frozen, in effecting the disintegration of rocks. (11.)

11. What are the two chief causes of differences in the pressure of the air at the sea-level? (11.)

12. How is the depth of the ocean determined? (11.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

You are permitted to attempt only *five* of the following questions.
The value attached to each question is the same.

21. I wish to compare the barometric readings taken at two places; what data with respect to these places will it be necessary for me to have, and why?

22. Explain why the influence of the moon is greater than that of the sun in causing tides.

23. What is "ground-ice," and under what condition is it formed?

24. How has the mass of Jupiter been determined?

25. What are the organisms that have the power of separating silica from sea-water, and what is the nature of the deposits formed by these organisms?

26. State what you know about variable stars.

27. State what you know concerning the mode of formation of different kinds of volcanic cones.

28. Describe the various forms of Nebulæ.

Honours Examination.

INSTRUCTIONS.

You are permitted to attempt *all*, or any, of the questions.
The value attached to each question is the same.

41. Give an account of the phenomena observed on the solar surface during a sun-spot period.

42. Describe a magnetic observatory.

43. Give an account of the metallic meteorites. What terrestrial rocks exhibit any resemblance to them?

44. Describe the characters of the cyclonic and anti-cyclonic movements of the atmosphere, north and south of the Equator respectively.

45. Give an account of the results which have been obtained by recent researches in connection with *one* of the following subjects :—

(*a*) The spectra of stars and nebulæ.
(*b*) The origin of serpentines.

SUBJECT XXIV. PRINCIPLES OF AGRICULTURE.

EXAMINERS, PROFESSOR HENRY TANNER, M.R.A.C., F.C.S.,
AND PROFESSOR JOHN WRIGHTSON, M.R.A.C., F.C.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

Each question admits of an answer carrying an equal number of marks.

1. What are the ashes of plants, and why do they differ in composition?

2. Mention any inorganic matter which is found in soils, and is useful for vegetation, but which is very rarely received into the plant. Explain its duties.

3. Distinguish between the dormant and active ingredients of the soil, and show by what means they change from the one condition to the other.

4. What do you understand by a soil being exhausted, and how does this condition arise?
5. Can you explain how it is that a soil may contain large stores of plant food, and yet such a soil may not be fertile?
6. Describe the advantages to be gained by fermenting farm-yard manure, and show how this fermentation can be most safely carried out.
7. Why are phosphates more generally necessary as manure than any other purchased manure?
8. In what forms do we use lime as a manure, and what are the special advantages of each?
9. What advantages are gained by land being properly drained?
10. How is it that an active cultivation of the soil enriches the land, and thus becomes a substitute for manure?
11. Describe the various constituents of food, and explain the duties they perform in the animal body.
12. What do you understand by a rotation of crops, and how should such rotations be arranged?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *six* questions.

Each question admits of an answer carrying an equal number of marks.

21. Name crops specially adapted for the following purposes:—
    (1) Summer feeding upon clay land by sheep.
    (2) Winter feeding upon light land by sheep.
    (3) Catch cropping.
22. Supply four characteristic examples showing that cultivated plants search for their food in different sections of the ground.
23. At what stage of its growth does a wheat crop cease to make further calls for plant food upon the soil?
24. Explain the fact that the clover crop is a good preparation for the succeeding wheat crop.
25. Under what conditions of soil, climate, and management would you expect to produce a first rate sample of malting barley?
26. Recommend suitable kinds and *quantities* of food for a fattin bullock, in the early, middle, and later periods of the fattening process. Also say how many times, and at what hours, he should be fed in the day.
27. In what sense do certain special manures tend to exhaust a soil; and how may such tendency be prevented by good farming?

28. Under what circumstances is the best farmyard manure produced? In answering this question you are not to enter upon the after-treatment, or management in the heap.

29. Enumerate the advantages of autumn cultivation for roots, and state upon what soils they are most apparent.

30. Name and briefly describe the best method of separating cream from milk.

31. Describe the various steps in the process of making Cheddar cheese.

32. Describe the feeding of bees during winter.

33. How would you ascertain whether eggs are fertile, and whether the germ is, and continues to be, alive?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to attempt more than *six* questions in this paper.

Each question admits of an answer carrying an equal number of marks.

41. From what sources have the various constituents found in our cultivated crops been derived, and how have they gained admission into these plants?

42. Describe the changes which nitrogenous matter undergoes in the soil.

43. Describe the circumstances and conditions which favour the growth of farm seeds possessing a healthy and vigorous character.

44. Select one of our established breeds either of cattle or sheep, and show the leading principles which are involved—
    (*a*) In the establishment of that breed,
    (*b*) In its maintenance in high quality.

45. Trace the changes which food undergoes in the body of the animal, and show how it is utilised for the growth of the body.

46. Describe the changes which take place in our root crops during their ripening, and notice the differences observable in their use as they are more or less matured.

47. Point out the essential conditions involved in the good management of a flock of sheep, early maturity of mutton, and a good fleece being desired.

48. Describe the formation of milk, and state the means whereby the flow may be made more or less abundant, as well as more or less rich in quality.

49. How should milk be treated in the dairy, when it is to be used for the production of butter? Mention a few matters which are important in a well-constructed dairy.

50. How does the breathing of impure air in badly ventilated buildings influence the milk produced, and the products manufactured from that milk?

51. Give an outline of the economy of the bee-hive, tracing the progress of the bee from its origin in the egg. State also the functions of queens and workers.

52. Describe the structure of an egg, and show the changes which it undergoes during incubation, and the means whereby we can favour healthy development.

SUBJECT XXV. HYGIENE.

EXAMINER, PROFESSOR W. H. CORFIELD, M.A., M.D. (OXON).

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *eight* questions.

The same value is attached to each question.

1. What are the most important food substances containing nitrogen, and how are they disposed of in the system?

2. What are the advantages of cooking by gas? What conditions should a gas-cooking oven fulfil?

3. What do we mean by "hard" and "soft" water? Which is better for domestic purposes, and why?

4. What is meant by "fermented drinks"? State the value of alcohol as a food substance.

5. How is the water of shallow wells liable to pollution? What diseases have been produced by the use of such waters?

6. What is the composition of the air? What are the variations in the amount of carbonic acid in pure air?

7. What is the composition of expired air, and why is it unfit to breathe again?
8. What are the forces which produce natural ventilation? How may the action of the wind be practically utilised?
9. Describe the appearances of wool, cotton, and silk fibres, and state the advantages of each as a material for clothing.
10. How does height above the sea affect the climate of a place?
11. What are the effects of bodily exercise on the respiration, circulation, and digestive apparatus?
12. How would you detect and arrest bleeding from an artery?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *five* questions.

The same value is attached to each question.

21. What are the most common adulterations of bread? How are they detected, and what is the importance of each?
22. How much lean beef, bread, butter, and water would be sufficient for an ordinary diet?
23. What impurities are most likely to be found in aërated waters, and what is their importance?
24. Describe the construction and action of an arrangement for filtering water on a large scale.
25. What are the best known methods for collecting and examining suspended substances in air?
26. What points should be attended to in the construction of a house-drain?
27. What is the importance of a dry basement floor, and how should it be secured?
28. What conditions favour the development of consumption, and what precautions should be taken for its prevention?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

The same value is attached to each question.

41. What are the methods for determining the amount of moisture in the air? How is that amount expressed? What is the importance of it?

42. What are the conditions which favour the spread of enteric fever? Discuss the question of the *de novo* origin of this disease.

43. Upon what principle does the Dry Earth System for the treatment of excretal matters depend? Under what circumstances is its adoption to be recommended?

44. Describe the processes adopted by an artificial manure maker, or by a soap-boiler. State the nuisances liable to be produced in either case, and the precautions you would adopt.

45. How should the death-rate of a town be calculated for the present year? How far are death-rates useful as indications of the healthiness of places? The death-rate of England was 20 per thousand per annum in 1884; state approximately how the various classes of diseases contributed to form that number.

46. For what purposes have Local Authorities powers under the Public Health Act to make bye-laws for houses let in lodgings? Frame a code of such bye-laws.

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EXAMINATION PAPERS

FOR

SCIENCE SCHOOLS AND CLASSES.

May and June, 1889.

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EXAMINATION PAPERS

FOR

SCIENCE SCHOOLS AND CLASSES.

MAY AND JUNE, 1889.

SUBJECT I. PRACTICAL PLANE AND SOLID GEOMETRY.

EXAMINERS, MAJOR G. S. CLARKE, C.M.G., R.E., and
T. H. EAGLES, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The constructions may be left in pencil, provided they are distinct and neat, and that the construction lines are shown. They must be strictly geometrical and not the result of calculation or trial. In the absence of those lines which are essential to a correct solution no marks will be awarded, however correct the result may appear.

Lines parallel or perpendicular to others may be drawn mechanically without showing any construction. Lines may be bisected by trial.

A single accent (') signifies *feet*; a double accent (") *inches*.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Questions marked (*) have accompanying diagrams.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions above.

Only *eight* questions are to be attempted.

Candidates for examination in Geometrical Drawing only may confine themselves to Section I.

Candidates for examination in the Elementary Stage of Practical, Plane, and Solid Geometry, must not attempt more than two questions in Plane Geometry.

SECTION I.

Plane Geometry.

*1. Convert the given scale into a diagonal scale reading inches. State the representative fraction of this scale. (8.)

2. Construct a scale of chords on a radius of 4·25″ to read to 5°. By means of this scale, plot an angle of 75°. (8.)

*3. Prick off the figure as given in Q. 7, and construct a similar figure, whose sides are to those of the given figure as 7 : 3. (8.)

*4. $a\,b\,c$ is a given triangle. Construct an isosceles triangle of equal area standing on $d\,e$ as base. (10.)

*5. Describe a circle of 1·25″ diameter touching each pair of adjacent lines $o\,a$, $o\,b$, $o\,c$, $o\,d$, produced if necessary. Describe two circles touching the three circles. (10.)

*6. The given figure is made up of circular arcs all of ¾″ radius. Draw it full size. (10.)

*7. Construct a six-sided polygon $a\,b\,c\,d\,e\,f$, such that $e\,f = \frac{a\,e}{2} = 3\,.\,a\,f$; $d\,e = a\,d$ and $a\,b = \frac{2}{3}\,.\,b\,c$. The rest of the data are given on the figure.

Scale ½″ = 10′·0″. (10.)

8. Construct a rhombus, side 2½″, diagonal 4¼″. In this rhombus inscribe an ellipse. (12.)

Solid Geometry.

9. A pentagonal right prism, side of base 1·5″, height 1″, rests on a horizontal plane. On it is placed a right cone, whose base circle touches the sides of the top of the prism. The height of the cone is 2″. Draw the plan and an elevation on a plane making 40° with one side of the base of the prism. (14.)

SECTION II.

10. A point is 2" from the vertical and 1·75" from the horizontal plane. Determine a point on the ground line distant 3·25" from this point. (10.)

*11. A is a point in the vertical plane; B a point in the horizontal plane. Draw the plan and elevation of the line A B. (10.)

*12. c' is the elevation of a point on the given line $a'\,b'$, $a\,b$; d is the plan of another point on the same line. Determine the real length of the line C D. (12.)

13. Construct an equilateral triangle of $2\frac{1}{8}''$ side. Consider the triangle to be the plan of a triangle A B C, such that the heights of the angles A, B, C, above the horizontal plane are $\frac{7}{8}''$, $1\frac{5}{8}''$, and $1\frac{1}{4}''$ respectively. Draw the plan of a horizontal line lying in the plane of the triangle and passing through C. (12.)

14. Draw the traces of two planes not at right angles to either plane of projection, and determine the angle which the intersection of these two planes makes with the vertical plane of projection. (12.)

15. The horizontal trace of a vertical plane makes 42° with the ground line. Determine the elevation of a line lying in this plane, inclined at 30°, and passing through the point where the given plane cuts the ground line. (12.)

*16. The given figure represents a picture frame. The plane of the picture is inclined at 55° and the long edges of the frame are horizontal. Draw the plan, neglecting the thickness. (14.)

17. A hexagonal right pyramid, side of base $1\frac{1}{2}''$, height $3\frac{1}{2}''$, stands on the horizontal plane. It is truncated by a plane parallel to and $1\frac{5}{8}''$ from its base. Suppose this truncated pyramid to be tipped about an edge of the base till the plane of one of the six side faces is horizontal. Draw the plan. (16.)

*18. The given figure represents the end view and part of the plan of an open box made of wood $\frac{3}{16}''$ thick. Complete the plan and make a sectional elevation on the line A B. (18.)

Graphic Arithmetic.

19. A line 2·6" long represents $4\frac{1}{2}$ units. Obtain lines representing 13; $\frac{10}{3}$, and $2\sqrt{6}$. (10.)

*20. If the given line A represents the unit, what numbers do the lines B, C, and D severally represent? Determine also a line representing $\dfrac{B}{C \times D}$. (12.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary Paper.

Only *eight* questions are to be attempted.

Plane Geometry.

*21. C D, C P are conjugate semi-axes of an ellipse. P M is drawn perpendicular to C D, and P N (on P M or M P produced) is made equal to C D. Show by construction that if the line M N slides between the lines C N and C D, the point P on it will trace out the ellipse. (16.)

*22. Draw through the given point A two lines containing an angle of 30°, and intercepting a length of 2″ on the given line B C. (18).

*23. Points P and Q are constrained to move uniformly along the given lines *a b* and *c d*. While P moves from O to *a* and back again, Q moves from *c* to *d*, and while P moves from O to *b* and back again, Q moves from *d* to *c*. Trace the locus of a point on Q P produced 2¾″ distant from Q. (18.)

Solid Geometry.

24. The vertical trace of a plane makes 40° with the ground line, and the plane is inclined at 50° to the horizontal plane. Draw its horizontal trace. Determine the point (P) in the plane 1″ in front of the vertical plane and 1½″ above the horizontal plane, and through P draw a line in the plane making equal angles with its traces. (20.)

*25. Find the intersection of the given plane and line A B, and through it draw a second line making the same angle with the plane as the first, and lying in the vertical plane containing A B. (20.)

*26. A solid (the plan and elevation of which are given) is made up of two exactly equal parallel crosses connected by the curved pieces seen in plan fixed to the horizontal arms. Draw its plan when it is rotated round the line K L, so that the line M N is also in the horizontal plane. (24.)

*27. The base of a right circular cone is in the given plane, and *c* is the plan of its centre. The slant side of the cone is in the horizontal plane. Draw its plan. (22.)

28. Two points are respectively 1·5″ and 0·75″ from both planes of projection. Their plans are 2·25″ apart. Determine a point on the ground line equidistant from both points. (24.)

29. A sphere of 2⅛″ diameter touches both planes of projection. A second sphere, diameter 1⅜″, touches the first sphere, and has its centre on the ground line. Draw the projections of the two spheres. (28.)

*30. The figure is the elevation of a truncated hexagonal pyramid. Draw the plan of this solid inverted, so that the plane of truncation is on the horizontal plane of projection. (26.)

31. A line 3″ long moves at a uniform speed round a vertical axis, by which it is bisected and to which it is always at right angles. At the same time it moves *along* the axis a distance of 1⅝″ for every complete revolution, thus generating a helical surface. Make a section of this surface by a parallel plane to and ¾″ from the fixed axis, the section to show two revolutions of the surface. (28.)

*32. Suppose that, in the given figure Q. 26, the curved pieces connecting the two crosses are replaced by a piece, square in section, and having *a′ b′ c′ d′* as its elevation. Determine the shadow of the solid thrown upon the horizontal plane, the direction of the parallel rays of light being given in plan and elevation. (28.)

Graphic Statics.

*33. A uniform rod A B, weighing 53 lb., is pivoted at A. If a force P of 32 lb. is applied at *c*, where must a parallel force of 41 lb. be applied to maintain equilibrium? (18.)

*34. Resolve the given force P (= 240 lb.) along the given lines *a a*, *b b*. Write down the magnitudes of the resolved components and indicate their directions by arrows. (20.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary Paper.

Only *eight* questions are to be attempted.

Plane Geometry.

41. Draw a square A B C D of 2″ side (the angular points being taken in order), and through C draw a line meeting A B in P and D A produced in Q, so that the area of the triangle P A Q shall be double that of the triangle P B C. (35.)

42. A line A B is $3\frac{1}{4}''$ long. Draw the locus of the vertex of the triangle described on it as base, the sides of which are in a given ratio (7 : 15). (35.)

43. A and B, two given points, are 2″ apart. A line is drawn through each, and these lines are turned round A and B with equal angular velocities. Draw the locus of their intersections—
1st. When they revolve in the same direction.
2nd. „ „ „ opposite „
The initial position of lines to be taken, one coinciding with A B and the other perpendicular to it. (35.)

Solid Geometry.

*44. A, B, C, D are four given points. Find the point in A D at which the segments A B, A C, subtend equal angles. Unit 0·1″. (45.)

*45. Determine a plane inclined at 65°, making 70° with the given plane and $\frac{3}{4}''$ distant from the given point. Unit 0·1″. (40.)

*46. A bar A B is suspended from two points C, D, by two equal strings, A C, B D, and is turned horizontally through two right angles so that it comes into the position shown by dotted lines on the elevation. Draw the elevation of the locus of the ends of the bar and make a section on the line L M of the surface it generates. (45.)

*47. A plane is given by its scale of slope, *a m* is the plan of a line in the plane and P an external point. Draw through A M a plane, making equal angles with the given plane and with the line P M. Unit 0.1″. (N.B.—M is a definite point on the line A M.) (50.)

48. A bead slides uniformly down a generator of a right circular cone (radius of base $1\frac{1}{4}''$, height $3\frac{1}{2}''$), starting from the vertex and reaching the base, while the generator traverses the conical surface one and a-half times. Draw the developed locus of the bead. (45.)

*49. A screw surface is generated by the revolution of the vertical semicircle A C B round the vertical circular cylinder, the diameter of which is A D. It rises from the position $a'\,c'\,b'$ to $a'_1\,c'_1\,b'_1$ in one revolution. Draw the elevation of the surface. (50.)

*50. A space (*a b c d* in plan) is to be covered in by a surface generated by a straight line which always intersects the semicircle A E B, the line C D, and a line the elevation of which is point *f′*. Draw the plan and elevation of the generator in at least eight positions, and determine the section of the surface by the vertical plane through L M. (Draw the figure double the size of the diagram.) (50.)

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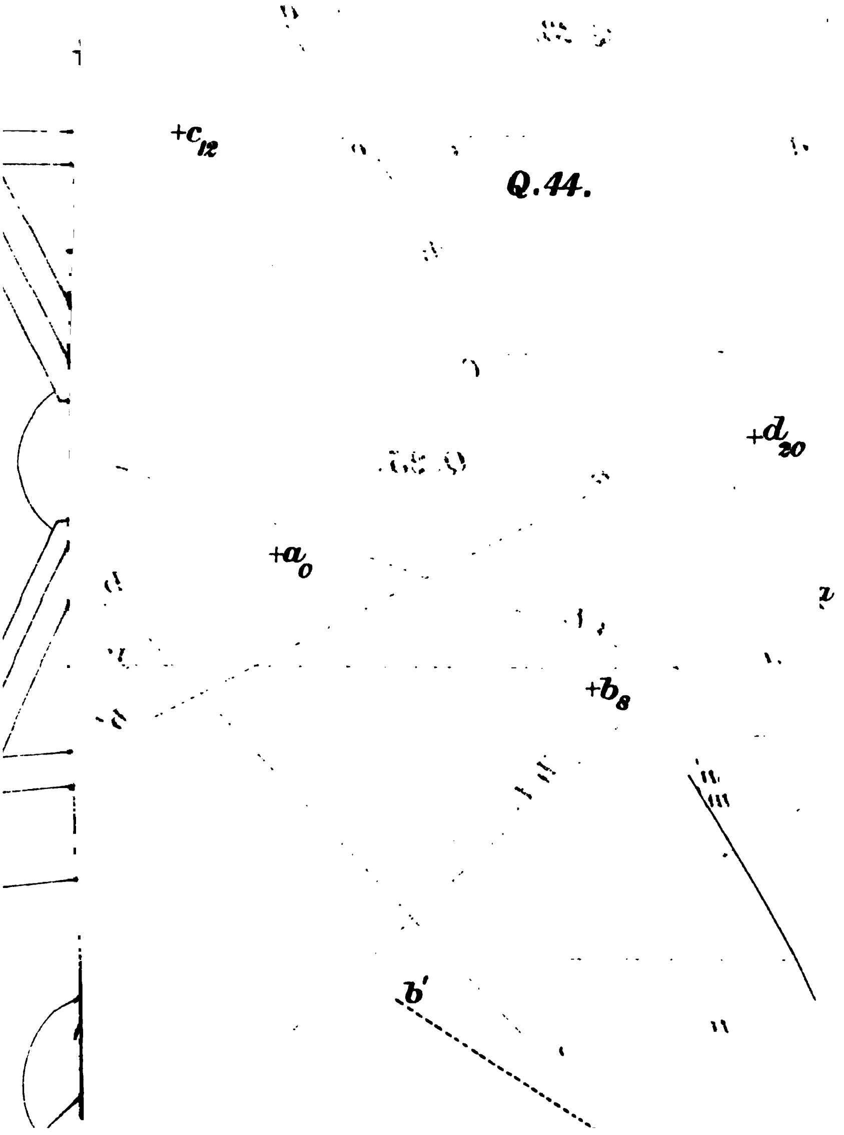
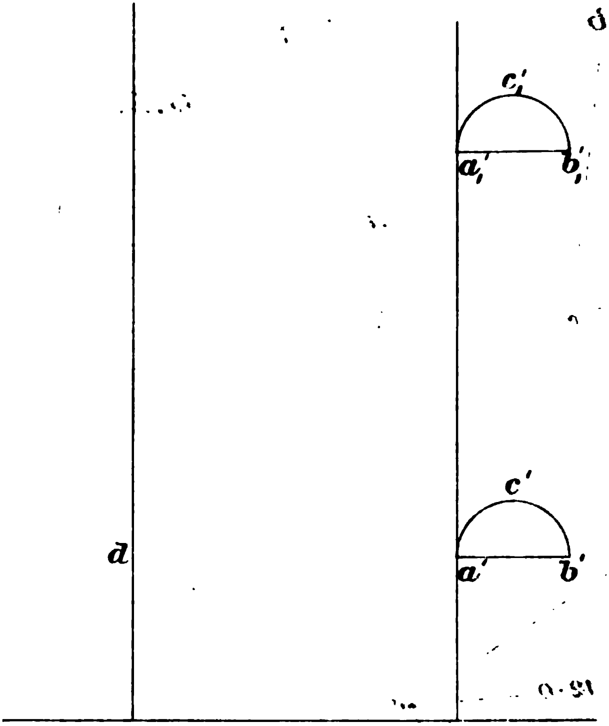
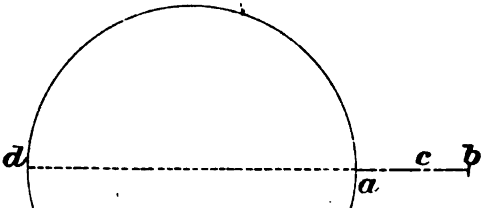
Q.44.





Q.49.



*51. A paraboloid of revolution (given by its elevation and plan of its axis) intersects an oblique cylinder, the axis (O M) of which is given, as also the plan of its base. Determine the projections of the intersection. (It will be seen that the axis of cylinder is parallel to planes of circular section of the paraboloid.) (50.)

*52. A rectangular panel, with diagonals and sphere at their intersection, is inclined as shown. Determine the shadow cast on the horizontal plane by rays proceeding from a point of which *s* is the plan, and the height of which above the horizontal plane is 4½″. (55.)

*53. Make a perspective view of the panel (Question 52) when standing vertical, with picture plane and station point as shown, the horizontal line being 3¾″ above bottom of panel. (55.)

Graphic Statics.

*54. The given figure (two circular quadrants) is the elevation of a flat disc of uniform thickness. Determine the point on the curved surface on which the solid would rest on a horizontal plane. (45.)

*55. The given roof truss is loaded as shown. The reaction at A is vertical. Determine and write down its magnitude and the direction and magnitude of the reaction at B. (45.)

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

EXAMINERS, PROF. T. A. HEARSON, M. INST. C.E., AND J. HARRISON, ESQ., M. INST. M.E., ASSOC. M. INST. C.E

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are expected to prove your knowledge of machinery, as well as your power of drawing neatly to scale. You are therefore to supply details omitted in the sketches, to fill in parts left incomplete, and to indicate, by diagonal lines, parts cut by planes of section.

No credit will be given unless some knowledge of projection is shown, so that at least two views of one of the examples will be required properly projected one from the other. The centre lines should be clearly drawn. The figured dimensions need not be inserted.

Your answers should be clearly and cleanly drawn in pencil. No extra marks will be allowed for inking in.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

A single accent (') signifies *feet;* a double accent (") inches.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions on p. 1.

Answer briefly any three, but not more than three, of the following questions, and draw two, but not more than two, of the examples.

Questions.

(*a.*) How is the joint shown in example 1 made water-tight? How are the bolts prevented from turning in the bolt-holes when screwing up the nuts? (6.)

(*b.*) When the eccentric strap shown in example 2 becomes loose by wear, how is it adjusted? What is the travel of the slide valve, the spindle of which is connected directly to the end of the eccentric rod? (6.)

(*c.*) What is the use of the water-gauge cock shown in example 3? State exactly where it is placed on the boiler. (6.)

(*d.*) Give sketches showing how a piston rod is secured to a piston. (10.)

(*e.*) Show by sketches how you would secure a piece of work to the table of a slotting machine. (10.)

(*f.*) Distinguish between a key and a cotter. Draw an example of each, stating the purpose for which each is employed. (10.)

Examples to be Drawn.

Diagram D.

1. Hydraulic pipe joint for high pressures. Draw and complete the two views shown and add a plan. Scale half size. (30.)
2. Eccentric and rod. Draw and complete the elevation shown and add a plan. Draw also a section of the strap and rim through AB. Scale ⅜ths. (35.)
3. Water gauge cock for steam boiler. Draw and complete the views shown, also add a plan. Scale full size. (35.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions above.

Answer briefly any three, but not more than three, of the following questions, and draw the example given.

(*g.*) What should be the lift of each of the valves of the pump shown in diagram E, so that the sectional area of the water passages may not be restricted? Of what materials should the several parts of the pump be made? (15.)

(*h.*) Sketch and describe a simple form of slide rest for a lathe. (15.)

(*k.*) A water tank with flat sides is to be built up of cast-iron flanged plates. Show clearly how you would construct a joint at one of the lower corners, where three plates meet, so as to ensure water tightness. (15.)

(*l.*) Give sketches showing how friction rollers are used to support a heavy rotating mass. Explain why the rollers should be coned, and in your sketch show the amount of coning necessary. (20.)

(*m.*) Sketch the profiles of the various forms of screw threads commonly employed in machinery, giving the proportions adopted. Point out the relative merits of the various forms, illustrating your answer with an example of the use of each. (20.)

(*n.*) Show by sketches a corner wall bracket to carry the pedestals of two horizontal shafts. The shafts are to be at right angles to one another and connected by bevel wheels. Show the shafts and wheels in position. (20.)

Example to be Drawn.

Diagram E.

Double-acting pump. Draw and complete the elevation, partly in section as shown, the valves and piston being placed in position, and not drawn separately as in the diagram. Complete the sectional plan and draw also a side elevation with the valve box cover removed. Show bolts or studs where required. (140.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on p. 1.

You are permitted to answer only *eight* of the following questions.

The sketches required in answer to these questions may be in pencil, and need not be drawn to scale, but should be neat and in good proportion. The written answers must be in ink, and may be written on foolscap paper, which can be obtained on application to the superintendents of the examination. Each sketch should be placed adjoining the answer to which it refers.

41. In making a flanged joint fluid tight by means of bolts and nuts, what considerations should be taken into account in estimating the size, number and strength of the bolts to be used?

Calculate the diameter and number of bolts you would use under the following circumstances:—The intensity of the fluid pressure is 100 lbs. per square inch, the total amount of the separating force due to the pressure is 10 tons, and the length of the flange measured along the pitch line of the bolts is 6 feet. (25.)

42. Sketch a swivelling crane suitable for raising weights, not exceeding 5 tons, by the power of 2 men, and give the following particulars relating to it:—

Radius of winch handle;

Mean crank effort when 5 tons is being raised;

Number of revolutions of winch handle per minute which may be expected: and speed of hoisting. (25.)

43. In a length of shafting subjected to a twisting moment only, explain why it is important to limit the angle of torsion of one end relatively to that of the other, besides limiting the stress to which the material may be subjected.

The angle of torsion of a cylindrical wrought-iron shaft is required not to exceed one degree for each 3 feet of length, and the stress not to be greater than 8,000 lbs. per square inch. Determine the diameter of the shaft above which the 2nd condition, and below which the 1st condition will fix a limit to the twisting moment which may be applied. (25.)

44. The crank shown in Fig. 1 is acted on by a force applied at C in the central plane of the crank at right angles to OC. It causes a bending moment on the shaft equal in magnitude to one-half the twisting moment produced. The crank is secured to the shaft by means of a sunk key. Determine the dimensions marked *a* and *h* in terms of *d* in order that the crank arm, key and shaft may be equally strong, allowing the stress on the material to be the same for each part. of *d* is 2″, find the sizes. (25.)

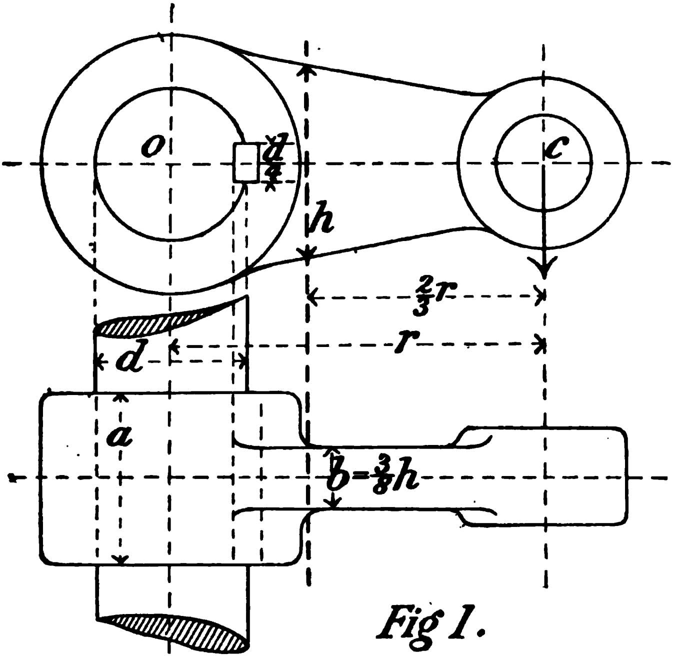


Fig 1.

45. Give sketches of the stern-tube and bearing for supporting the after length of a screw-propeller shaft. Show how the corrosion of this portion of the shaft is prevented; how the water is prevented from leaking through the bearing into the ship, and how the heating of the bearing may be discovered and prevented. Estimate the diameter of this portion of the shaft for an engine of 4,000 horse-power, making 90 revolutions per minute. (25.)

46. Describe fully, and illustrate with sketches, the preparation of a mould for casting a screw propeller of large size. (25.)

47. Give sketches showing how railway points are moved with precision by a signalman in a distant cabin. Point out how the effect of extension of the length of the connecting rods by heat is eliminated, friction diminished, and permanent changes of length adjusted. (25.)

48. Give sketches showing the construction of a stop or communication valve for one of a set of boilers, the valve to be capable of closing automatically when the pressure in the boiler is less than in the steam pipe. Estimate the dimensions of the valve for a boiler of 500 horse-power, the pressure being 120 lbs. per square inch. (25.)

49. Make sketches showing the construction of a pressure-reducing valve capable of regulation, and explain its mode of action. Mention some purposes for which such a valve is applied. (20.)

50. Give sketches of the construction and explain the action of a water *or* gas meter. (25.)

51. With the aid of sketches describe the construction of a swivelling pipe joint by which water pressure may be transmitted to a crane which revolves, or has a limited travel. (20.)

52. State the object of a brake, and point out the advantage possessed by a hydraulic brake as compared with one of rigid material. Describe and give sketches of an example of a form of hydraulic brake or buffer by which a nearly constant arresting force may be obtained, stating the purpose for which the brake is used. (25.)

53. Give sketches and describe the action of some kind of instant-grip bench-vice. (20.)

54. Give sketches showing the form of the teeth and worm in worm-wheel gearing. Explain fully how you would proceed to estimate the various dimensions of the parts of such a gearing required to rotate the worm-wheel shaft against a given resisting moment. (25.)

55. Explain how the varying velocity of the reciprocating parts of a locomotive engine causes forces tending to displace the engine from the rails, and show how this action may be to some extent balanced. Give an approximate estimation of the position and magnitude of the balance weights. (25.)

56. Draw and describe a diagram representing the straining effect of a tensile load on a bar of mild steel, the load being gradually increased to about three-fourths the breaking load and then alternately taken off and put on a few times. Describe also some of Wöhler's experiments on the effect of unlimited repetition of loads, and state some of the conclusions at which he arrived as to safe ranges of stress. (25.)

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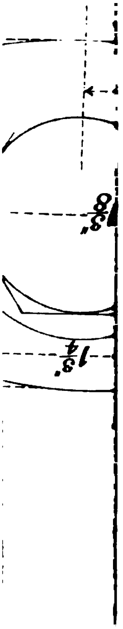

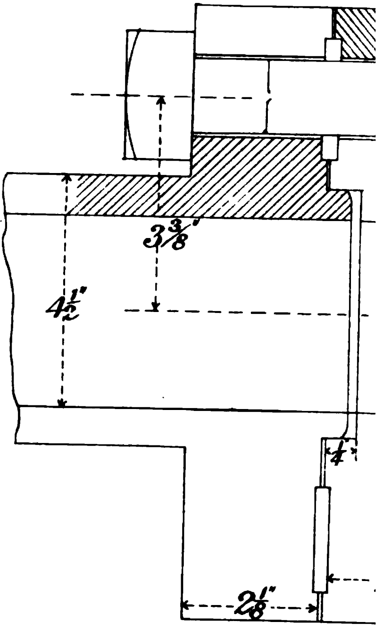

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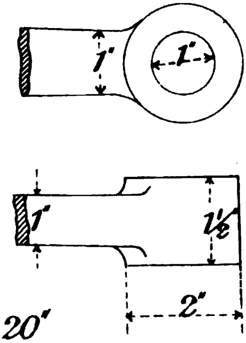


rod 20″

2″

SUBJECT II. MACHINE CONSTRUCTION AND DRAWING.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at home. The drawings, &c., are to be sent by post to the Secretary, Department of Science and Art, London, S.W., on or before the 22nd of June. The postage need not be prepaid. The drawings should be as fully detailed as possible, and carefully dimensioned. Some marks will be allowed for inking-in and colouring, but more credit will be attached to good proportion and fulness of detail.

Give all the calculations which you make.

The following voucher must be signed and returned with the worked drawings:—

I, ______________________________________

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Machine Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed)__________________________
No.________

The above number must be quoted on each separate sheet of drawings worked by you.

The subject for design is a centrifugal pump, suitable for effecting a lift of 16 feet, and delivering 1,500 cubic feet of water per minute.

Drawings are required showing the construction of the pump, but not the engine for driving it.

If the pump wheel is placed in a masonry pit, the position and construction of the supply and discharge culverts should be shown, and all necessary frames and bearings for supporting the wheel shaft.

If the wheel is surrounded by a cast-iron casing, assume the length of the supply and delivery pipes to be each 20 feet; but in your drawings it will be sufficient to show the ends of these pipes attached to the casing.

In the specification, besides your calculations for strength, give the estimation of the following quantities:—

Velocity of the wheel periphery, and revolutions per minute;

Velocity of the water at all points in the line of flow;
Turning moment and horse-power exerted on shaft; and
Longitudinal thrust on shaft (if any).

Also, give a graphical construction for the form of the spiral path of the water through the wheel, and draw to scale a diagram representing the velocity, pressure, and level components of the total head of the water throughout its progress through the pump, taking for a base line the length of the path of the water through wheel and surrounding chamber.

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E. (Ret.).

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary or the Advanced or the Honours paper, but you must confine yourself to one of them.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

All figures must be drawn on the single sheet of paper supplied, for no second sheet will be allowed.

All drawings must show a correct knowledge of construction. Neat, distinct, and accurate pencil drawing to scale is required. No extra marks will be allowed for inking-in. Where only sketches are asked for the proportions must be approximately correct, though extreme accuracy, as in drawings to scale, is not necessary.

You are to confine your answers *strictly* to the questions proposed.

Put the number of the question before each answer.

Answers in writing must be as short and clearly stated as possible, and close to any figures to which they may refer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

A single accent (′) signifies *feet;* a double accent (″) *inches.*

Questions marked (*) have accompanying diagrams.

The Examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *seven* questions.

---

*1. Plan of the angle of a brick building built in English bond.
Draw, to a scale of ½" to a foot, showing the joints of the bricks by single lines. (11.)

*2. Sketch, showing the end of a beam to be connected with a similar one by an ordinary scarfed joint.
Give a plan and elevation of the joint to a scale of 1" to a foot. (11.)

3. Explain by sketches, or otherwise, the following terms:—edges shot—ploughed, tongued and V-pointed—mortised and housed. (11.)

*4. Section of a stone wall built of coursed, flat-bedded, rubble.
Draw, to a scale of ¾" to a foot, showing the stones in the wall, including two ¾ bond stones, and adding a flush stone coping, weathered at top. (11.)

*5. Vertical cross section through the joints of a stone landing.
Draw, to a scale of $\frac{1}{12}$, showing at A a rebated joint, and at B a joggled joint. (11.)

*6. Single line section of a cast iron girder, 10" × 4" × 15" deep.
Taking the thickness of the top and bottom flanges at 1½" and 1" respectively, draw its section, ¼ full size, and state how such a girder ought to be used. (12.)

7. Draw, to a scale of ¼, cross sections of the joints you would use in the lead gutter of a roof, to connect the ends of the sheets together. (12.)

*8. Elevation of the back of a framed and braced door.
Draw, to a scale of ¾" to a foot, making any alteration you think advisable, and filling in with rebated and beaded battens. Only the joints in connection with the hanging stile to be dotted in. (13.)

9. Give, to a scale of ¾" to a foot, sections across a few floor boards showing the construction of—
A single floor with 1½" boards, rebated and filleted.
A double floor with 1½" boards, grooved and tongued. (13.)

*10. Line diagram of an iron roof truss.

Draw, ⅓ full size, an elevation of the joint at the head of the truss, the members consisting of T irons 2¾" × 2½" × ½" and two bars 2¼" × ¼". (13.)

11. Draw, to a scale of 3′ to an inch, a cross section through a wooden roof over a 16′ span, showing—

Rafters, 4" × 2".
Collar, 4½" × 2", half way up.
Ridge piece, 7" × 1½".
Wall plates, 4" × 2".
Brick walls, 14".

The rise to be ⅓ span, and the rafters not to be weakened in connecting the collar to them. (14.)

12. Draw, to a scale of ⅛, a cross section through a lead gutter at the back of a chimney shaft, showing all the details of construction, the rafters being 4" × 2", carrying Countess slates (3 courses to be shown) on ¾" boards. (15.)

*13. Elevation of a 4½" trussed partition, to be constructed out of 9" × 3" and 9" × 2" deals.

Give its elevation, to a scale of 8 feet to an inch, writing against them the names and scantlings of the different members. (16.)

*14. Horizontal section through a window 1′ 8" × 2′ 6", to be fitted with a casement sash, hung to a solid frame, and opening inwards.

Draw a vertical section through A—A, to a scale of 1½" to a foot, showing a stone head and sill, a 1¼" window board, and a 2" sash, which must be weather-tight. (16.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions.

21. Describe the following bricks, stating the purposes for which they are suitable:—Shippers, grizzles, malm cutters, blue Staffords. (12.)

22. What is the composition of the following stones; which would you consider the most durable, and why?
York stone, Bath stone, Craigleith stone. (12.)

23. Explain what is meant by rich lime, poor lime, stone lime.
Which will carry the most sand, and why? (12.)

*24. Diagram of a loaded truss.
Draw, to double the size, omitting as many members as possible, and marking with a × all the remaining members brought into compression by the load. (14.)

*25. Plan of a fireplace in a ground floor room.
Draw, to a scale of $\frac{1}{24}$, a section through A—A, showing all the detail of the construction. (14.)

*26. Plan showing the junction of a 1½-brick wall built in Flemish bond, with a 2-brick wall built in English bond.
Show, to a scale of ¾" to a foot, the arrangement of the bricks in two successive courses. (14.)

*27. **Plan of a cross-beam framed into two girders.**
Draw, to a scale of 1½" to a foot, sections through the joints, showing at A a shouldered or tusk-tenoned joint, and at B a chase-mortised joint.
Under what circumstances would the latter joint be used? (16.)

28. Give a part elevation and a cross section of a plate girder 2 feet deep, with a ¼" web, connected to flanges, each consisting of two 12" × ⅜" plates; the rivets to be ¾" diameter, with a pitch of 4". (16.)

29. Draw, to a scale of 3 feet to an inch, an elevation of about half of a wooden roof truss for a 34 feet span, containing the following members:—

Tie-beam, 10" × 5".
Queen posts, 5" × 3½".
Principals, 5" × 5".
Straining beam, 5" × 6".
Braces, 4" × 2½". (16.)

*30. **Vertical section through the base of the outer wall of a brick dwelling-house built on a damp site.**
Draw, to a scale of ½" to a foot, showing the joints of the brickwork, and making any alterations or additions you consider necessary to prevent the damp from affecting the walls. (17.)

31. Give a cross section, to a scale of 1" to a foot, through the ridge of a slated roof, showing three courses of Duchess slates centre nailed on 3" × 1" battens, with 4" × 2"

rafters, and a 9″ × 1½′ ridge-piece finished with slate ridging.

Also give a similar section showing the details of a lead ridge roll. (17.)

*32. Elevation of a 2″ door, glazed above with nine panes and two panels below, bead flush outside and moulded inside.

Draw, to a scale of ¾″ to a foot, the outside elevation; also a section through A—A, to double the scale. (18.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions.

41. In what respects does seasoned differ from unseasoned timber? When would you consider fir timber sufficiently seasoned for use in carpenters' and joiners' work respectively?

Name any artificial systems of seasoning timber you may be acquainted with, omitting the details of the processes. (8.)

42. A brick building is to be repointed with Portland cement mortar; write out a specification to govern the work. (8.)

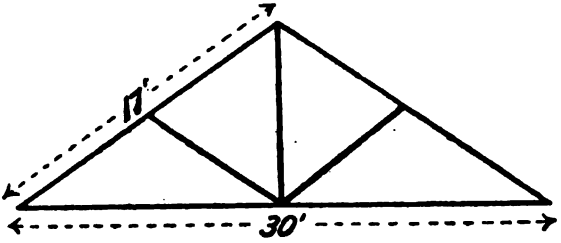
43. A girder of uniform section, which has safely carried a distributed load of 4 tons over a 12 feet span, is now required to carry 2 columns at 4 feet from the supports and from each other.

Taking each column to be equally weighted, what should the load on each be limited to in order not to increase the stress on the beam. (8.)

44. State briefly the difference between cast-iron, wrought-iron, and steel; and by what treatment they can be distinguished one from the other. (8.)

45. Taking the ordinary vertical load per foot super for a wooden slated roof, including wind and snow, and a ceiling weighing 10 lbs. per foot super on the tie, determine geometrically, or otherwise, the nature and extent of the

direct stresses set up in the different members of the truss below, the trusses being at 10 feet centres and the weights concentrated at the joints of the truss. (8.)



46. The diameter of a Doric column being taken as 4 feet, draw its horizontal section and elevation, to a scale of $\frac{1}{36}$; showing how the architrave and frieze were treated by the Greeks, and writing the names of the different parts against them. (8.)

47. Give a horizontal section, $\frac{1}{8}$ full size, through one jamb of an internal doorway in a first class dwelling-house. The wall to be of 9″ brickwork, rendered outside, and lath and plastered on battens inside the room. The wood fittings and a portion of the door to be shown. (10.)

48. Draw, to a scale of 4 feet to an inch, a cross section through one-half of a wooden roof over a 36 feet span, the trusses being 10 feet apart, ceiled to the tie-beams, and resting on 20″ stone walls. The eaves to be finished with fascia and soffit boards, and cast-iron ogee gutters. The scantlings of the different members to be given. (10.)

49. Give explanatory sketches of the first flight, containing 10 flyers, of a wooden staircase 4′ 6″ wide, in a first class dwelling-house; showing all the details of its construction, including the balusters and hand rail. (10.)

50. Give, to a scale of $\frac{3}{4}$″ to a foot, an elevation and section, showing all the details of a suitable pair of folding doors, for an entrance doorway 4′ × 8′, to a town mansion. (10.)

51. Give a section, to a scale of $\frac{1}{12}$, of a brick sewer with a sectional area of about 7 feet, to be laid along the centre of a main street, about 8 feet below road level.

Also draw, to about half the above scale, a section of a man-hole leading to the same. (10.)

52. Write out a specification to govern the covering of a roof, in a very exposed site, with Countess slates, including lead-work in gutters, hips, valleys, and ridges. (10.)

SUBJECT III. BUILDING CONSTRUCTION.

EXAMINER, COLONEL SEDDON, R.E. (Ret.).

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidate at his own home. The drawings are to be sent by post to the Secretary, Department of Science and Art, London, S.W., on or before the 22nd of June. The postage need not be prepaid.

Draw up a design for a pair of semi-detached shop cottages for a small country village, to be built on a plot of ground with a 70-feet frontage and a depth of 150 feet.

They are to be kept 20 feet back from the frontage, standing in their own gardens, which are only to be separated by a low fence.

The site is rather low-lying, and damp at times, but the foundations are sound.

Each is to have the following accommodation:—

Shop area of about 200 feet superficial, with a living room, small kitchen and larder, and three bedrooms.

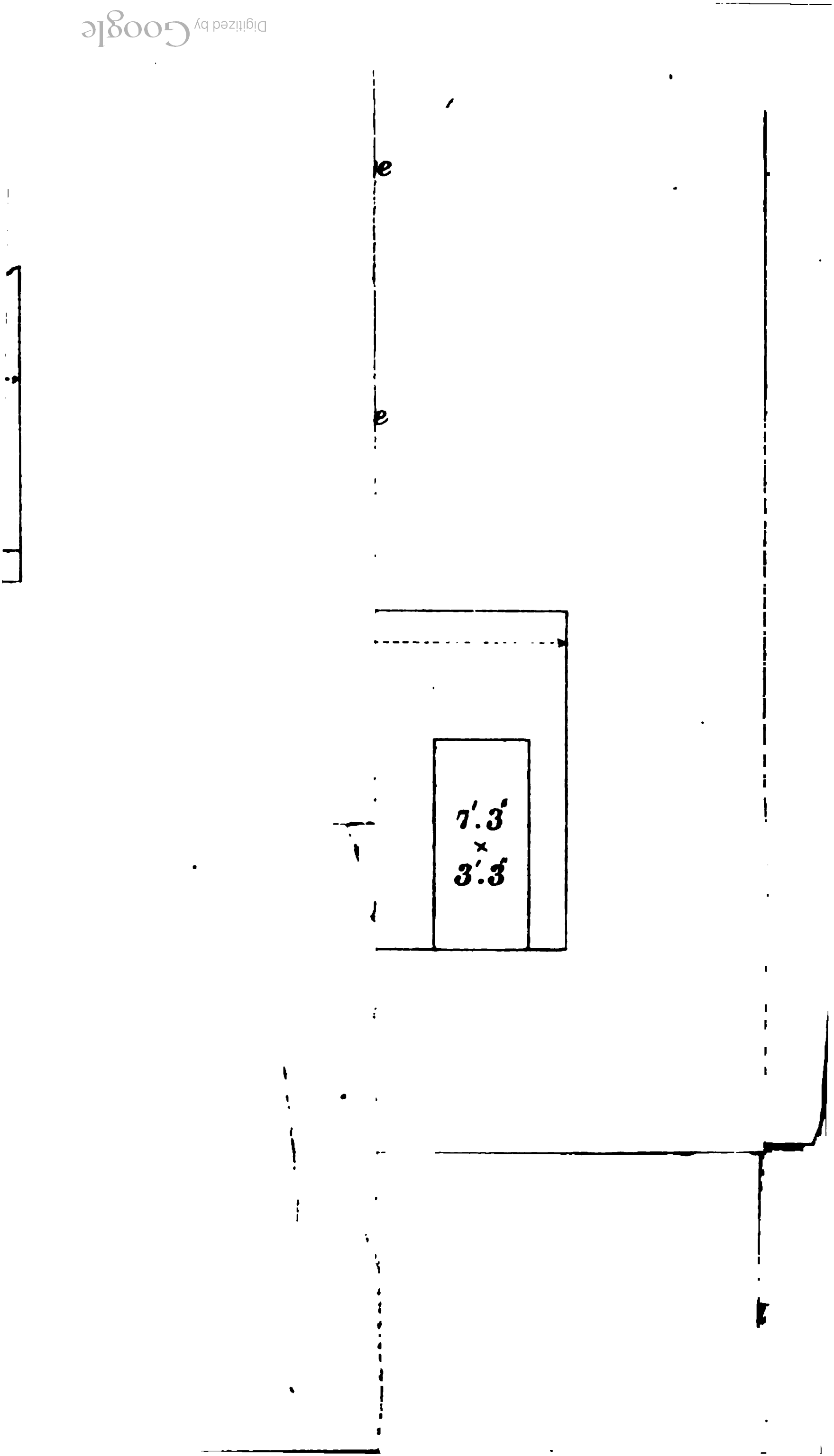
One of the shops is to be a post office, with fancy goods, and the other a drapery store.

The choice of materials is left to the candidate.

All the work must be sound and good, the rooms conveniently arranged, and all sanitary requirements carefully attended to.

Plans and elevations to be drawn to a scale of 8 feet to an inch, sections to twice the scale of the plans, and enlarged details to be given as may be required. A small site plan to be given, showing positions of any out-offices.

The drawings must be fully dimensioned, and sufficiently complete to allow of accurate bills of quantities being taken out from them, with the exception of out-buildings, which need only be shown on the general plan.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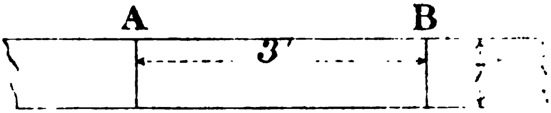


The approximate cost of the block, ascertained by cubing out the contents, to be stated, and a *short* description given of the materials proposed to be employed, and of any points requiring explanation.

The following voucher must be signed and returned with the worked drawings :—

I, ______________________________

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Building Construction and Drawing, have been wholly done by me, and without assistance from any person.

(Signed)______________________________

No. ____________

The above number must be quoted on each separate sheet of drawings worked by you.

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them. Sketches, required to be made *to scale, must be inked in with drawing pen.*

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The value attached to each question is shown in brackets after the question. A full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

The examination in this subject lasts for four hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *ten* questions.

You must *attempt No.* 21. Two of the remaining questions may be selected from the Calculations; **and the rest from one, but not from both, of the sections of Practical Shipbuilding.**

PRACTICAL SHIPBUILDING.—SECTION I.
WOOD AND COMPOSITE SHIPS.

1. Sketch roughly :—(1) a plain scarph;
(2) a tabled scarph. (8.)

2. How is the keel of a wood ship set to its right position on the blocks, and how is it usually secured thereon? (6.)

3. How is the stern post of a wood ship usually connected with, and fastened to the keel? How is water prevented from getting behind the bottom plank through the joint of the stern post and keel? (8.)

4. The frames of a small wood ship are trimmed, and ready to be hoisted into place on the blocks, state briefly how the work of erecting and fixing them in place is proceeded with. (12.)

5. What is :—(1) chain bolting;
(2) frame bolting.
Briefly explain how the work is proceeded with in each case? (8.)

6. What is the "shelf"? Show how the shelf, beams, waterway, and frames are usually connected together. (10.)

7. How would you take an account of, trim, and get in place a strake of bottom plank?
In wood ships, which of the outside planks are usually first fitted, and for what reasons? (12.)

8. Show how the flat keel plate, transverse frames, and intercostal keel plates are usually connected together in a composite vessel. (12.)

9. How are the frames of a composite vessel usually bent and bevelled? (8.)

10. Explain how the work of laying the wood deck, and securing it to the iron beams, in a composite vessel, is proceeded with, to ensure good workmanship. (8.)

PRACTICAL SHIPBUILDING.—SECTION II.
IRON AND STEEL SHIPS.

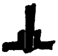
11. Roughly sketch a "tap" rivet. Where are such rivets used, and how are they got into place and finished off? (8.)

12. Roughly sketch:—(1) a side bar keel;
(2) a flat plate keel;
and show how the bottom plating is connected to the keel in each case. (8.)

13. Show by a rough sketch how you would connect and fasten the heel of a stern post to a side bar keel. (8.)

14. The frames of a small steel vessel are ready to be hoisted into place on the blocks, how would you proceed with the work of erecting and temporarily securing them in place? (12.)

15. A bottom plate has great curvature, how would you make sure that it will properly fay against the frames, and how would you take an account of the rivet holes in it? (12.)

16. A girder of the form  passes through a watertight bulkhead, how would you make the bulkhead watertight around the girder? (10.)

17. How would you ascertain that the iron beams are ready to receive the wood deck? (6.)

18. Explain how the work of laying the wood deck, and securing it to the iron beams, is proceeded with to ensure good workmanship. (8.)

19. Sketch roughly any two kinds of fastenings which have been extensively used for fastening wood deck to iron beams. (8.)

20. Explain how the bottom plates are caulked, and how the rivets and joints are tested to see if they are tight. (12.)

DRAWING.

21. What does sketch No. 21 represent? Enlarge it to a scale twice the size shown. (14.)

CALCULATIONS.

22. Write down:—(1) Simpson's 1st Rule;
(2) Simpson's 2nd Rule
for finding the areas of plane surfaces, and state under what conditions each rule is applicable. (8.)

23. The "half"-ordinates of the midship section of a vessel are 12·7; 12·8; 12·9; 12·9; 12·9; 12·8; 12·5; 11·9; 10·4; 5·9 and 1·4 feet respectively, and the common interval between them is 18 inches.

Find the area of the section in square feet. (6.)

24. A Dantzic oak deck plank is 25′ 6″ long and 4½″ thick. It is 8″ wide at one end, and tapers gradually to 6″ at the other end, what is its weight? (6.)

25. What is meant by "tons per inch immersion"?

The "tons per inch immersion" at the load water plane of a ship is 30·5, what is the area of the load water plane? and what would be the displacement in c. ft. and in tons, of a layer 4″ thick in the vicinity of this plane? (6.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *twelve* questions.

You must attempt No. 49. The remaining questions may be selected from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

31. Show how the keel, floors, keelson, and garboard strakes of a wood ship are usually connected and fastened together. (6.)

32. How would you trim a piece of wood stem? (8.)

33. How are the wood frames proved to be in their right positions on the keel, and how are they temporarily secured in place? (6.)

34. Mention the different asemblages of plank on the outside of a wood ship. State where they are worked, and which you consider the most important in giving strength to resist hogging and sagging strains, stating your reasons. (8.)

35. Show in plan, and in elevation, how the flat keel, frames, and intercostal keel, are usually connected together in a composite vessel. (8.)

36. Describe the work of "fastening" the "outer" thickness of bottom plank in a composite vessel which has two thicknesses of bottom plank. (6.)

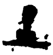
IRON AND STEEL SHIPS.

37. Explain how the work of framing a mercantile vessel of the ordinary type is proceeded with. (8.)

38. Sketch a portion of a bracket frame extending from the middle line of the ship to just beyond the first longitudinal from the middle line. (8.)

39. How are steel rivets tested to ascertain if they are fit for use? (8.)

40. A bottom plate has great curvature, how would you make sure that it will properly fay against the frames, and how would you take an account of the rivet holes in it? (8.)

41. A girder of the form  passes through a watertight bulkhead, show clearly how you would make the bulkhead watertight around the girder. (8.)

42. The outer bottom plating in some vessels is worked so that the inside strakes are broader than the outside strakes by twice the width of the lap. In other vessels the inside and outside strakes are worked of equal breadths.

Discuss the relative merits of the two systems. (8.)

43. What principles should govern the arrangement of pillars in a ship?

Which form of pillar:—

(1) solid bar,

(2) tubular with solid head and heel;

is preferable? Why? (8.)

44. Sketch roughly any two kinds of fastenings which have been extensively used for fastening wood deck to iron beams.

What are the requirements of Lloyd's Register as to fastenings of deck planks? (8.)

LAYING OFF.

45. Describe briefly the work of fairing the body upon the mould loft floor. (8.)

46. How are the edges of the bottom plates and longitudinals obtained, and faired, on the mould loft floor? (8.)

47. How would you lay off a harpin? (6.)

48. What moulds and information should be given to the workmen to enable a harpin to be trimmed and fixed in its place? (6.)

DRAWING.

49. What does sketch No. 49 represent?
Enlarge it to a scale twice the size shown. (12.)

CALCULATIONS.

50. When would you use

(1) Simpson's 1st Rule,
(2) Simpson's 2nd Rule,

for finding the area of a plane surface?

The "half"-ordinates of a water plane of a vessel, in feet, are respectively, commencing from "forward":— 0·3; 3·8; 7·6; 10·2; 11·5; 11·5; 11; 9·5; 6·7; and 2; and the common interval between them is 16 feet.

Find—

(1) the area of the plane in square feet;
(2) the distance of the centre of gravity of the plane "abaft" the "foremost" ordinate; (8.)

51. Explain briefly the method of finding the displacement of a ship from her drawings. (6.)

52. What is the "centre of buoyancy"?

The load displacement of a ship is 5,000 tons, and the centre of buoyancy is 10 feet below the load water-line. In the light condition the displacement of the ship is 2,000 tons, and the centre of gravity of the layer between the load and light lines is 6 feet below the load line.

Find the vertical position of the centre of buoyancy below the light line in the light condition (6.)

53. The ordinates of the boundary of the deck of a ship are:— 6·5; 24; 29; 32; 33·5; 33·5; 33·5; 32; 30; 27 and 6·5 feet respectively, and the common interval between them is 21 feet.

The deck, with the exception of a space of 350 square feet, is covered with $\frac{3}{8}''$ steel plating, worked flush-jointed with single riveted edges and butts. Find the weight of the plating, including straps and fastenings. (8.)

54. In arranging the butt fastenings of the bottom plates of a ship, what principles would guide you in determining the rows of rivets, and the spacing of the rivets, in the butt straps? (6.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *fourteen* questions. You may select these from any part of the paper, provided that one or more be taken from each section, viz., Practical Shipbuilding, Laying Off, and Calculations.

PRACTICAL SHIPBUILDING.

WOOD AND COMPOSITE SHIPS.

71. Show roughly, in plan, extending from a few feet on one side of the middle line of a ship, to the topsides on the other side; how the timbers comprising a frame and a filling frame would be arranged; and show the frame bolting. (6.)

72. How would you take an account of, trim, get in place, and temporarily secure, a strake of bottom plank which is a shutter-in lengthwise? (8.)

73. Specify generally, without giving dimensions, the requirements of Lloyd's Register as to:—
(1) floor plates;
(2) flat keel plates;
in composite vessels. (6.)

74. Show roughly, in plan and elevation, how the floor plates, flat keel plate, and intercostal keel plates, are connected and fastened together in a composite vessel, specifying sizes of plates and angles; and sizes and pitches of rivets, stating the approximate size of the vessel you take. (8.)

75. Briefly compare:—
(1) as to local strength;
(2) as to structural strength;
a wood vessel and a composite vessel of similar dimensions. (6.)

IRON AND STEEL SHIPS.

76. Sketch roughly, by transverse sections extending from the middle line of ship to just below the turn of the bilge, illustrating :—
    (1) the bracket-plate system of framing;
    (2) the framing of a small mercantile vessel of ordinary type. (8.)

77. Show how the bottom plating is connected with, and fastened to, the stern post in a large war ship, showing how the edges of the plates are formed and strapped in the vicinity of the post. (8.)

78. Describe the tests to which Z steels are subjected to ascertain if they are fit for use. (6.)

79. Describe clearly, with a sketch, how you would secure watertightness in a watertight bulkhead where a steam pipe passes through it. (6.)

80. What general principles should govern the arrangement of pillars in a ship?
    Which form of pillar is preferable :—
    (1) solid bar;
    (2) tubular with solid head and heel?
    Why? (6.)

81. It is found necessary to increase the strength of the upper deck of a steel vessel which has no plating on that deck.
    For a given weight of material, discuss briefly, giving your reasons, whether you would :—
    Work fore and aft diagonal tie plates on the beams associated with stringer plates of small dimensions on the ends of the beams;
    or
    dispense with the tie plates and work stringers on the ends of the beams of larger dimensions. (8.)

LAYING OFF.

82. Explain the order in which you would lay off a large iron or steel ship.
    State what moulds you would have made, and the order in which you would send them out from the mould loft. (8.)

83. A ship trims considerably by the stern, and has a list to port; how would you find the true form of the plane of flotation? (4.)

84. Show, by rough sketches, a bilge keel in the sheer, half-breadth, and body plans.

State the reasons for the positions and directions chosen. (6.)

85. How would you obtain an account of a longitudinal which has great curvature and twist?

Show what information you would give to the workmen in order that the plate may be prepared for use. (6.)

CALCULATIONS.

86. From the particulars given below find—

(1) the displacement in tons of the vessel up to L.W.L.;
(2) the distance of the centre of buoyancy abaft the foremost station;
(3) the depth of the centre of buoyancy below L.W.L.

Half-ordinates in feet at stations:—

	1	2	3	4	5
L.W.L.	·3	8·9	13·2	11·2	2·4
2 W.L.	·3	6·4	12·6	7·8	·4
3 W.L.	·3	2·4	9·0	3·1	·4

Stations apart 27 feet.
Water lines apart 3 feet.

(Appendages before and abaft end ordinates, and below No. 3 W.L. being neglected.) (8.)

87. A pontoon raft is formed by three cylindrical pontoons each 50 feet long and 4 feet in diameter. The outer pontoons are each 8 feet from the middle one (centre to centre) throughout their lengths.

Find the displacement of the raft, and the height of the transverse metacentre above the centre of buoyancy, the pontoons floating with their axes at the surface of the water. (8.)

88. Explain briefly how the vertical position of the C.G. of a ship and its equipment is accurately obtained. (6.)

89. How is a metacentric diagram constructed, and what are its uses?

In what classes of ships would you expect the metacentre to fall quickly as the draught lightens, and after reaching a minimum height to gradually rise again? (6.)

90. A steel ship is found on her first voyage at sea to be structurally weak longitudinally. How would you attempt to effectually strengthen the ship with the least additional weight of material, giving your reasons? (6.)

91. What is meant by "curves of weight" and "curves of buoyancy" as applied to the longitudinal distribution of weight and buoyancy in ships?

Show how these curves are obtained; and draw, approximately, on the same scale and in one diagram, such curves for any type of vessel with which you are acquainted; mentioning the type you have taken. (6.)

SUBJECT IV. NAVAL ARCHITECTURE.

EXAMINER, J. H. MORRISON, ESQ., R.C.N.C.

Honours Examination.—Work to be done at Home.

INSTRUCTIONS.

This paper is to be worked by the Candidates at their own homes. The drawings are to be sent by post to the Secretary, Department of Science and Art, London, S.W., on or before the 22nd of June. The postage need not be prepaid.

101. Portions of the sheer and body plans of a steel screw vessel on a scale of ⅛ inch to 1 foot, with particulars of dimensions, are given on drawing No. 101.

Make a *complete* building draft on a scale of ¼ inch to 1 foot from the information furnished, and:—

(1.) Mark distinctly on the drawing constructed by you the position of the centre of buoyancy when the vessel is floating at a load line of 11′ 6″ forward; 12′ 6″ aft.

(2.) Construct the curve of displacement on a scale of 1 inch per foot of draught, and 1 inch per 100 tons displacement.

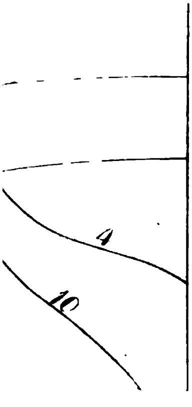
(3.) Construct the curve of tons per inch immersion on a scale of 1 inch per foot of draught, and ¾ inch per ton.

SUBJECT IV.

L.

— ADVANCED STAGE.

No. 49.



The following voucher must be signed and returned with the worked drawings:—

I, ________________________________

hereby certify on my honour that the drawings sent in by me, for the Honours Examination in Naval Architecture, have been done wholly by me, and without assistance from any person.

(Signed) ________________________

No. ________

The above number must be quoted on each separate sheet of drawings, &c., worked by you.

SUBJECT V. PURE MATHEMATICS.
STAGES 1, 2, & 3.

EXAMINERS, REV. J. F. TWISDEN, M.A.,
AND A. R. WILLIS, ESQ., M.A., D.SC.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You are permitted to answer questions from the First Stage, or from the Second Stage, or from the Third Stage, or from the Honours Paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Every page of the paper supplied for the answers may be used.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

All the work by which a result is obtained must be clearly shown *in immediate connexion with the question.* No credit will be allowed for any result, however correct it may be, unless the work be shown, so as to enable the Examiners to satisfy themselves that the candidate has understood the question, and to see by what process the result has been obtained.

Anything which you do not wish the Examiners to notice should be crossed out with the pen.

A table of logarithms must NOT be used in working these papers. All the logarithms needed will be found on the accompanying paper.

Unless you expressly state the contrary, it will be assumed that you have read GEOMETRY *in Euclid, and you will be expected to follow Euclid's sequence. Otherwise, you must state what text book you have used in geometry.*

The examination in this subject lasts for three and a half hours.

Mathematics, First Stage.

INSTRUCTIONS.

Read the General Instructions above.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

A.

1. **Simplify**:—

(*a*.) $$\frac{7\frac{2}{3}}{4\frac{2}{11}} \text{ of } \frac{24}{77} - \frac{(3\frac{4}{7} - 2\frac{5}{6}) \text{ of } 3\frac{3}{13}}{3\frac{4}{7} - 2\frac{5}{6} \text{ of } \frac{24}{119}}.$$

(*b*.) $(0{\cdot}0011 \times 0{\cdot}091 \div 0{\cdot}0035) + (0{\cdot}015 \times 0{\cdot}507 \div 0{\cdot}39)$. (10.)

2. Extract the square root of 0·029 to five places of decimals, and the cube root of 2,248,091.

The volume of a cubical block is 2248·091 cubic feet; find the area of one of its faces. (10.)

3. Find the value of 2 tons 3 qrs. 22 lbs. of goods at £8 19*s*. 8*d*. per cwt. (8.)

4. Find (*a*) the value of 7¼ per cent. of £125 4*s*. 10*d*., and (*b*) what profit per cent. is made when £7 4*s*. 11*d*. are gained by an outlay of £123 6*s*. 8*d*. (10.)

5. Divide £3 18*s*. 4*d*. among three persons, A, B, C, so that B may receive seven-eighths as much as A, and C five shillings more than B. (10.)

6. A mètre being equal to 39·371 inches, and a franc being equal to 9·38 pence, what is the value in English money of a yard of silk worth 7½ francs a mètre? (10.)

B.

7. If you had a ruler and a pair of compasses, how would you bisect a given finite straight line?

Prove that the method you employ is correct.

In the triangle ABC the side AB is greater than AC; find a point D in AC produced, such that AD may be as much greater than AC as AB is greater than AD. (10.)

8. Show that any two sides of a triangle are together greater than the third side.

In the triangle ABC the side AB is greater than AC, produce BA to D, making AD equal to AC, and join DC; show that the angle DCB is greater than a right angle. (10.)

9. Show that the straight lines, which join the extremities of two equal and parallel straight lines, towards the same parts, are themselves equal and parallel.

In the triangles ABC, DEF, the side AB is equal and parallel to DE, and BC is equal and parallel to EF; show that AC is equal and parallel to DF. (14.)

10. Show how to describe a parallelogram, which shall be equal to a given triangle, and have an angle equal to a given angle.

A triangle ABC is equal to a rectangle DEFG; the side DE equals half the base BC: show that the perimeter of the rectangle is less than that of the triangle. (12.)

11. Define a square, a rhombus, and a quadrilateral.

If a quadrilateral has its diagonals at right angles to each other, show that the sum of the squares on two opposite sides equals the sum of the squares on the other two opposites sides. (12.)

12. In the triangles ABC the angles at A and C are each half a right angle; AD is drawn bisecting the angle at A and meeting BC in D; show that the square on DC is double the square on BD. (14.)

C.

13. If $2x = 3$ and $y = -0{\cdot}4$, find the values of the following expressions:—

(*a.*) $20(x - 2y)(x + 4y)$, (*b.*) $\dfrac{4x - 8}{3y + 1}$,

(*c.*) $\dfrac{\dfrac{1}{x} + \dfrac{1}{y}}{\dfrac{1}{x} - \dfrac{1}{y}}$ (*d.*) x^2y^3 (12.)

14. Write down the following expressions in factors:—

$$(a.)\ x^2 + 7x - 30, \qquad (b.)\ 10x^3 - 40xy^2,$$
$$(c.)\ x^3 + x^2y + xy^2 + y^3. \qquad (9.)$$

15. Divide $6x^4 + x^2y + 2x^2 - 12y^2 + 37y - 28$ by $2x^2 + 3y - 4$, and verify your result by putting $x = 2, y = -1$ in divisor, dividend, and quotient. (10.)

16. Solve the equations:—

$$(a.)\ \tfrac{1}{5}(2x + 1) - \tfrac{1}{3}(x - 2) = x - 24\tfrac{3}{1},$$
$$(b.)\qquad 1{\cdot}35x + 0{\cdot}1y = 12{\cdot}2.$$
$$\frac{x}{3} - \frac{y}{0{\cdot}4} = 1{\cdot}75. \qquad (12.)$$

17. The numerator of a certain fraction is 4 less than the denominator; if 10 be subtracted from the numerator, or if 30 be added to the denominator, the resulting fractions would be equal; find the original fraction. (14.)

18. A man employs thirty men and twenty women, and pays them £8 17*s.* 6*d.* a day, each man receiving the same wages, and each woman the same wages. If he had employed two more men and two fewer women, he would have paid £9 3*s.* 6*d.* a day; find how much he paid each man and each woman. (14.)

Mathematics, Second Stage.

INSTRUCTIONS.

Read the General Instructions on the first page.

The paper is divided into three sections. You are not to answer more than three questions in any one section, and not more than eight questions altogether. No student can be passed who fails to obtain marks in any one section.

The number of marks assigned to each question is given in brackets.

A.

21. Reduce the following fraction to its simplest form:—

$$\frac{x^3 - 5x^2 - 8x + 12}{x^4 - 7x^3 + 7x^2 - 7x + 6},$$

and find its numerical value to five places of decimals when $x = 1 + \sqrt{3}$. (15.)

22. Simplify the following expressions:—

$$(a.)\ \sqrt{(52 - 7\sqrt{12})},$$
$$(b.)\ \frac{1 - \sqrt{2} + \sqrt{3}}{1 + \sqrt{2} + \sqrt{3}} - \frac{1 - \sqrt{2} - \sqrt{3}}{1 + \sqrt{2} - \sqrt{3}}. \qquad (15.)$$

23. Find the values of x which satisfy the equations:—

$$(a.)\ 6x^2 - 13x + 6 = 0$$

$$(b.)\ 2x - \sqrt{(x^2 + 4)} = 3.$$

After solving equation (*b*), show by direct substitution that one of the values, which you have found, satisfies the equation. (25.)

24. The price of one kind of sugar is 2*s*. 8*d*. per cwt. more than that of another kind, and £1 will purchase 20 lbs. less of the first kind than of the second; find the price per cwt. of each kind of sugar. (20.)

25. If the triplicate ratio of x to $x + y$ is 1 to 1·728, what is the ratio of x to y? (15.)

26. Six gallons of wine are drawn from a cask, and replaced by six gallons of water; six gallons of the mixture are then drawn, and replaced by six gallons of water. If the quantity of wine, now in the cask, be to the quantity of water in it as 81 to 19, find how much wine there was in the cask at first. (25.)

B.

27. If a straight line is bisected and produced to any point, show that the rectangle contained by the whole line thus produced, and the part produced, together with the square on half the line, is equal to the square on the line made up of the half and the part produced.

In a right angled triangle show that the square on the perpendicular equals the rectangle under the lines which are severally equal to the sum and difference of the hypotenuse and base. (20.)

28. If equal straight lines (AP, AQ) be drawn from a point A to a given straight line of indefinite length, and if a third straight line AR be drawn from A to a point R in the given straight line, show that AR is shorter or longer than AP, according as R is between P and Q or not.

What property of the circle follows from this theorem? (20.)

29. Show that the opposite angles of any quadrilateral inscribed in a circle are together equal to two right angles.

Two given circles intersect in A and B; on the circumference of one of them take any two points C and D, and let CA, BD, produced if necessary, cut the other circle again in E and F. Show that the lines CD and EF are parallel. (25.)

30. Show that the lines, drawn from a point outside of a circle to touch the circle, are equal.

Show that the hypotenuse of a right angled triangle, together with the diameter of the inscribed circle, equals the sum of the sides containing the right angle. (20.)

31. P is any point in the diameter AB of a given circle; bisect AP in D, PB in E, and DE in C; with centre C and radius CD describe a circle; through P draw any line PQR cutting this circle in Q and the given circle in R. Show that PQ is equal to QR, and that the tangent at Q to the inner circle is parallel to the tangent at R to the outer circle. (30.)

32. Show how to construct a rectangle which shall be equal to a given square, and have the difference between two adjacent sides equal to a given straight line. (20.)

C.

33. State and prove the rule for finding the characteristic of the logarithm to the base 10 of a given number. Write down the logarithms of 2736·7 and 0·027367.

Find log. tan 35° 15′ 48″ and the numerical value of $\sqrt[3]{(\frac{1}{2}\sin 44°)}$. (20.)

34. What are the numerical values of a right angle in circular measure and in sexagesimal measure?

Find in circular measure the numerical value of an angle, which in sexagesimal measure is 37° 15′.

The radius of a circle being 105 feet, find the length of the arc which subtends an angle of 37° 15′ at the centre. (20.)

35. Show how to construct an angle of 45°, and find from the constuction the sine, cosine, tangent, and cotangent of 45°.

Show how to construct an angle of 15°, and find from the construction the sine of 15°. (20.)

36. Show that in any triangle the sides are proportional to the sines of the opposite angles.

AB is a line 2,000 feet long; B is due east of A; at B a distant point P bears 46° W. of north; at A it bears 8° 45′ E. of north; find the distance from A to P. (25.)

37. Write down formulæ for the values of the sine, cosine, and tangent of the half of any one of the angles of a triangle whose sides are given.

If the sides of the triangle are 7, 8, and 9 units long, find the sine of half the smallest angle, and the angle itself to the nearest second. (25.)

38. The angular elevation of a tower at a certain station is A; at another station, in the same horizontal plane, and a feet nearer the tower, the angular elevation is 90° — A; if h be the height of the tower above the horizontal plane, show that

$$h(1 - \tan^2 A) = a \tan A.$$

Calculate h, when $A = 30°$ and $a = 100$ feet. (25.)

Mathematics, Third Stage.

INSTRUCTIONS.

Read the General Instructions on the first page.

You must confine your answers entirely to Sections A and B, or to Sections A and C; and you must not answer more than *four* questions in either section.

You must not answer more than eight questions altogether.

The number of marks assigned to each question is given in brackets.

A.

41. What is the meaning of a^m, when m is a positive whole number? Bearing the definition in mind, explain how a meaning is assigned to the symbols $a^{\sqrt{2}}$ and $a^{-\frac{1}{2}}$.

Find in a decimal form the numerical value of $(\frac{3}{8})^{\sqrt{3}}$. (35.)

42. Solve the equations :—

$$2y - yz = 4, \quad 2z - zx = 9, \quad 2x - xy = 16.$$

(30.)

43. The pth, qth, rth, and sth terms of an arithmetical progression are in geometrical progression; show that $p - q$, $q - r$, and $r - s$ are in geometrical progression.

Find the quadratic equation whose roots are respectively a geometric mean and a harmonic mean between those of the equation $x^2 - 3x + 9 = 0$. (35.)

44. Show from first principles that the number of combinations of n things r at a time is equal to the number of combinations of $(n - 1)$ things r at a time, together with the number of combinations of $(n - 1)$ things $(r - 1)$ at a time.

Find how many words of 4 consonants and 2 vowels can be formed from 7 consonants and 4 vowels. (40.)

45. C is the point of contact of two circles, which touch each other internally, and CPQ is a straight line, cutting the inner circle at P and the outer circle at Q; the tangent to the inner circle at P cuts the outer circle at A and B; show that the arc AQB is bisected at Q. (40.)

46. Two unequal circles intersect at A; show how to draw a straight line PAQ, cutting the one circumference in P and the other in Q, so that PA may equal AQ. (35.)

B.

47. Find geometrically sin A and cos A in terms of sin $\frac{1}{2}$A and cos $\frac{1}{2}$A, when A is less than a right angle.

Show that the formulæ hold good, when A is between $\frac{3\pi}{2}$ and 2π. (30.)

48. Calculate the numerical values of the following expressions:—

(*a*.) Cotan 54° 45′ cotan 157° 48′.

(*b*.) Sin 30° 39′ − sin 78° 49′. (35.)

49. Show that in any triangle ABC:—

(*a*.) $\text{Sin}\,A + \sin B + \sin C = 4\cos\frac{A}{2}\cos\frac{B}{2}\cos\frac{C}{2}$,

(*b*.) $$\text{Cos}\,\frac{A}{2} + \cos\frac{B}{2} + \cos\frac{C}{2} = 4\cos\frac{\pi - A}{4}\cos\frac{\pi - B}{4}\cos\frac{\pi - C}{4}$$

(*c*.) $\text{Cos}\,A + \cos B + \cos C > 1$. (40.)

50. ABCD is a quadrilateral inscribed in a circle, and the sides AB, BC, CD, DA are denoted by a, b, c, d; show that—

$$(s - b)\tan\frac{A}{2} = (s - d)\tan\frac{B}{2},$$

where s denotes the semiperimeter. (35.)

51. If R denotes the radius of a circle circumscribing a triangle ABC, show that

$$R(a^2 + b^2 + c^2) = abc(\text{cotan}\,A + \text{cotan}\,B + \text{cotan}\,C).$$ (35.)

52. An equilateral triangle ABC, whose area is denoted by Δ, is divided into two triangles by a line drawn through A; the perpendicular distances from this line of B and C are p and q respectively; show that

$$p^2 + pq + q^2 = \Delta\sqrt{3}.$$ (40.)

C.

53. Show that the angles at the base of an isosceles spherical triangle are equal.

If a spherical triangle is isosceles, show that its polar (or supplemental) triangle is also isosceles. (30.)

54. Show geometrically that the sines of the angles of a spherical triangle are proportional to the sines of the opposite sides.

Given $A = 136°$, $a = 155° 55'$, $b = 144° 45'$, find B. (35.)

55. In a spherical triangle ABC, show that:—

(*a*.) $\operatorname{Cos} C + \cos A \cos B = 0$, if $c = 90°$.

(*b*.) $\operatorname{Sin} a = \sin A \sin c$, if $C = 90°$.

In a spherical triangle (ABC), if C be a right angle, and A have a fixed value less than a right angle, while the other parts vary, show that the difference between b and c is a maximum, when their sum is equal to a quadrant. (40.)

56. ABC is a spherical triangle; calculate the angle A when—

(*a*.) $C = 90°$, $B = 45°$, $c = 120°$,

(*b*.) $C = 90°$, $b = 135°$, $c = 120°$. (30.)

57. Demonstrate Napier's Analogies.

ABC is a spherical triangle; given $c = 60°$, $A - 75°$, $B = 15°$; find a and b. (40.)

58. Having given a small circle, whose spherical radius subtends an angle of 60° at the centre of the sphere, and a great circle, whose pole is on the circumference of the small circle, find to the nearest second the angle subtended at the centre of the sphere by the common chord. (35.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.

You may not answer more than ten questions.

The same value is attached to each question.

61. Take any points E and F in the sides AC, AB of a triangle ABC; join EF, and draw from A a straight line, passing through the middle point of EF and cutting BC in D; show that

$$CA \cdot AF \cdot BD = BA \cdot AE \cdot CD.$$

62. C is the centre and AB the diameter of a semicircle ADEB; the tangent at D intersects the tangents at A and E in F

and G, respectively; AE and CG intersect in H; show that FH is perpendicular to CG.

63. ABC is an equilateral triangle; a circle intersects AB in D, AC in E, and BC produced in F; it also intersects AC, AB, CB, all produced in G, H, and K, respectively; show that

$$AE + BK + CG = AD + BH + CF.$$

Find the corresponding result, when all the vertices of an equilateral triangle are inside a circle, which intersects the sides of the triangle produced both ways.

64. Ax, Ay are two lines at right angles to each other, and within the angle xAy a circle of given radius is drawn to touch Ax and Ay; find points P and Q in Ax and Ay such that the straight line PQ is of given length and touches the circle on the side remote from A. What is the least admissible length of PQ?

65. If $a + b + c = 0$, show that

$$\frac{a^7 + b^7 + c^7}{7} = \frac{a^5 + b^5 + c^5}{5} \frac{a^2 + b^2 + c^2}{2}.$$

If $a^3 + b^3 + c^3 = (a + b + c)^3$, show that—

$$a^{2n+1} + b^{2n+1} + c^{2n+1} = (a + b + c)^{2n+1},$$

where n is any positive integer.

66. If a, b, c, d, e are unequal positive numbers, show that $(a + b + c + d + e) \div 5 > (abcde)^{\frac{1}{5}}$.

67. Eliminate x from the equations—

$$3x - 2x^3 = a$$
$$(1 + 2x^2)\sqrt{(1 - x^2)} = b.$$

68. Obtain the law of formation of the convergents to a continued fraction, and show that any convergent is nearer to the continued fraction than any other fraction which has a smaller denominator than that of the convergent.

$$\text{If } x = \frac{1}{a +}\,\frac{1}{b +}\,\frac{1}{a +}\,\ldots,$$

$$y = \frac{1}{2a +}\,\frac{1}{2b +}\,\frac{1}{2a +}\,\ldots;$$

$$z = \frac{1}{3a +}\,\frac{1}{3b +}\,\frac{1}{3a +}\,\ldots,$$

show that—

$$x(y^2 - z^2) + 2y(z^2 - x^2) + 3z(x^2 - y^2) = 0.$$

69. If $\sin^3\theta = \sin(A - \theta)\sin(B - \theta)\sin(C - \theta)$,
where $A + B + C = \pi$,
show that

$$\cot \theta = \cot A + \cot B + \cot C.$$

70. In a given circle equal chords of given length are drawn, containing a given angle; supposing them to intersect within the circle, and to meet the circumference at A, C, B, D, find the sides of the quadrilateral ABCD.

Also find the results if the chords intersect outside the circle.

71. P is any point on the line bisecting at right angles one of the n sides of a regular polygon inscribed in a circle; show that the product of the distances of P from the angular points is $\alpha^n + \beta^n$, where $\alpha + \beta$, and $\alpha - \beta$ are the distances from the middle points of the larger and smaller arcs, cut off by that side.

72. Write down $\sin\theta$ and $\cos\theta$ in factors.

If n is a very large number, show that—

$$\sqrt{\frac{(2n+1)\pi}{2}} = \frac{2 \cdot 4 \cdot 6 \cdot 8 \ldots 2n}{1 \cdot 3 \cdot 5 \cdot 7 \ldots 2n-1}.$$

73. ABC is a plane triangle in which a is less than b; assuming the exponential expressions for the sine and cosine of an angle, show that

$$A = \frac{a}{b}\sin C + \frac{a^2}{2b^2}\sin 2C + \frac{a^3}{3b^3}\sin 3C + \ldots.$$

$$\frac{b^n}{c^n}\cos nA = 1 + n\frac{a}{b}\cos C + \frac{n(n+1)}{1 \cdot 2} \cdot \frac{a^2}{b^2} \cdot \cos 2C + \ldots.$$

74. Find an expression for the radius of the small circle circumscribing a given spherical triangle.

If R and R′ are the radii of the small circles circumscribing a spherical triangle (ABC) and its polar triangle show that

$$\cot R \cot R' = 4\sin\tfrac{1}{2}A\sin\tfrac{1}{2}B\sin\tfrac{1}{2}C\cos\tfrac{1}{2}a\cos\tfrac{1}{2}b\cos\tfrac{1}{2}c.$$

75. Show that the area of a spherical triangle (ABC) is to that of half the surface of the sphere on which it is described, as the spherical excess (E) is to four right angles.

Let the great circle through M, N, the middle points of AC, AB, meet BC produced in P; from the arc PB cut off PX equal to $\frac{1}{2}a$, and from PN cut of PY equal to MN; show that XY equals $\frac{1}{2}$E, and that if the area of the triangle ABC be one-fourth of the area of the sphere, the arcs joining the middle points of its sides are each quadrants.

76. A solid angle at P is contained by three plane angles, viz., BPC = CPA = α and APB = γ; O is a point in PC; with centre O and radius OP describe a sphere, and suppose that A, B, C are on the surface of the sphere; join BC, CA, AB by arcs of great circles; show that

$$\cos A = \frac{\cos 2\alpha \sin \frac{1}{2}\gamma}{\sin \alpha \sqrt{(1 - 4 \cos^2\alpha \sin^2\frac{1}{2}\gamma}}.$$

Tables required.

Angle.		Log. Sin.
°	′	
24	5	9·610 7263
	6	1 0118
35	15	9·761 2851
	16	4638
44	0	9·841 7713
54	44	9·911 9422
	45	2 0315
79	15	9·992 3106
	16	3346

Angle.		Log. Tan.
°	′	
22	12	9·610 7586
	13	1 1196
35	15	9·849 2536
	16	5216
63	26	10·300 9994
	27	1 3153

Number.	Logarithm.
2	301 0300
3	477 1213
17012	230 7554
3	7809
17317	238 4727
8	4977
23560	372 1753
1	1937
27367	437 2272
61406	788 2108
7	2179

$\sqrt{2} = 1{\cdot}414214$

$\sqrt{3} = 1{\cdot}732051$

SUBJECT V. PURE MATHEMATICS, STAGES 4 and 5.

EXAMINER, P. T. WRIGLEY, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Fourth Stage, or from the Fifth Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The figures in descriptive geometry should not only be constructed with ruler and compasses, but the construction should in all cases be explained and its accuracy demonstrated.

You are to confine your answers *strictly* to the questions, proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Fourth Stage.—Subjects: Plane, Solid, and Descriptive Geometry and Geometrical Conics.

INSTRUCTIONS.

You are not permitted to attempt more than *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

1. Inscribe a regular pentagon in a given circle, and in the pentagon inscribe a regular figure of ten sides, having its alternate sides coincident with the sides of the pentagon. (16.)

2. In the triangles ABC, DEF, the angle ABC is equal to the angle DEF and the sides about these angles are proportional: show that the angle BAC is equal to one of the two angles EDF, DFE, and give the ratio of the third sides of the two triangles.

MPQ, NPR, are two intersecting circles such that the sum of the squares on their radii is equal to the square on the distance between their centres. Show how to draw a straight line MPN such that the rectangle MP, PN shall be equal to a given square. (18.)

3. When are quantities said to be in continued proportion? Divide a given finite straight line into two parts such that the whole line and the two parts shall be in continued proportion.

The perpendicular let fall from the right angle to the hypotenuse of a right angled triangle divides the hypotenuse in mean and extreme ratio: show that the three sides of the triangle are in continued proportion. (18.)

4. When is a line said to be perpendicular to a plane, and when parallel to the plane?

From a given point, how many lines can be drawn perpendicular to a given plane, and how many parallel to that plane?

The angle B of the triangle ABC is a right angle: P is a point, not in the plane of the triangle, and equidistant from A, B, and C: if a straight line PD bisect AC, prove that PD is perpendicular to the plane ABC. (18.)

5. Prove that the volume of a pyramid is one-third the volume of a prism on the same base, and of the same altitude.

Two planes are drawn parallel to the base of a given cone so as to trisect its altitude; find the volume of the frustum intercepted between these planes. (18.)

6. Show that the area of the surface of a sphere is four times the area of a plane central section.

C is the middle point of the arc ADCEB of a semicircle whose diameter AB is 12 inches in length: the perpendicular distances from AB of the points D and E are 3 and 2 inches respectively; join DE, and find the area of the surface generated by the revolution of the segment DCE about AB. (20.)

7. Having given the traces of a plane, both of which are oblique to the axis, and also the projections of two points, one on each side of the plane; find the traces of the line joining these points, and the point where this line meets the given plane. (16.)

8. Having given the traces of a plane which cuts the axis and is not perpendicular to either plane of projection, also the horizontal projection of a point on the plane; find the traces of two planes which shall pass through this point and be perpendicular to each other and to the given plane. (18.)

9. If two of the plane angles of a trihedral angle are given, and also the dihedral angle between the planes of these

two; show how to construct, by descriptive geometry, the third plane angle, and one of the other two dihedral angles. (18.)

10. If the tangents at any two points P, Q, on a parabola intersect at T, and S be the focus; show that the triangles SPT, SQT are similar, and that ST is a mean proportional between SP and SQ.

P is any point on the common tangent of two given parabolas which have the same focus; if SM, SN be the perpendiculars let fall on the two other tangents drawn from P, show that SM and SN are in a constant ratio. (20.)

11. If CP, CD be conjugate semi-diameters of an ellipse, and S, H the foci, prove SP . HP $= CD^2$.

Having given the sum of the distances of a point P from two fixed points, and also the rectangle contained by these distances; determine the position of P. (20.)

12. A and B are two fixed points, and P is a moving point such that the difference of the distances PA, PB, is constant; show that the perpendicular distance of P from a certain fixed straight line is in a constant ratio to PA.

If an ellipse and a hyperbola have the same foci, show that the curves cut each other orthogonally. (18.)

Fifth Stage.—Subjects: Descriptive Geometry, Spherical Trigonometry, Co-ordinate Geometry of two and of three dimensions.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage Paper.

You are not permitted to attempt more than *eight* questions, and may select them from any part of the paper.

The marks assigned to the questions are shown in brackets.

21. A sphere of given radius rests on the horizontal plane at a given point: the sphere is enveloped by a cylinder, the vertical trace of whose axis is given. Find the curve in which the cylinder meets the horizontal plane. (30.)

22. A right cone on a circular base has its axis inclined at given angles to the planes of projection. Find the form of the

section made by a plane, cutting the axis at a given point, and inclined to the axis at a given angle. Find also the projections of the normal to the conical surface at any given point of the curve of section. (35.)

23. ABC is a spherical triangle: show that—

$$\cos\frac{A+B}{2}\cos\frac{c}{2}=\cos\frac{a+b}{2}\sin\frac{C}{2},$$

$$\sin\frac{A+B}{2}\,.\cos\frac{c}{2}=\cos\frac{a-b}{2}\,.\cos\frac{C}{2},$$

and prove that—

$$\cos\frac{b}{2}\sin\frac{a}{2}\sin\frac{C-B+A}{2}+\cos\frac{a}{2}\sin\frac{b}{2}\sin\frac{C+B-A}{2}$$
$$=\sin\frac{c}{2}$$

(35.)

24. ABC is a spherical triangle: points A′, B′, C′ are taken on the sides BC, CA, AB respectively, or on these sides produced.

If $\sin AB'\,.\sin BC'\,.\sin CA' = \sin AC'\,.\sin BA'\,.\sin CB'$, show that either AA′, BB′, CC′, meet at a point, or A′ B′ C′ lie on a great circle. (40.)

25. Obtain an expression for the area of a spherical triangle whose angles are known.

a, *b*, *c* are the sides of a spherical triangle; having given $\cos a = \cos b = \sqrt{3}\cos c = \frac{1}{\sqrt{3}}$, show that the area of the triangle is $\frac{1}{24}$th of the surface of the sphere. (35.)

26. Investigate the equation of a straight line in terms of its inclination to the axis of *x*, and its perpendicular distance from the origin.

Find the equation of the straight line which joins the intersection of the lines $3x - 4y + 1 = 0$, and $5x + y - 1 = 0$ to the point (1, 3). Indicate the position of these three lines by a diagram, and find the tangent of the angle between the two given lines. (35.)

27. Obtain the equation of a parabola, referred to the axis of symmetry and a line at right angles to it, through the vertex, as the axes of co-ordinates.

Tangents are drawn to a parabola, whose equation is $y^2 - 4ax = 0$ from the point $(4a, 6a)$, and the points of contact are joined. Find the area of the triangle thus formed. (35.)

28. Define conjugate diameters of an ellipse, and show that the sum of the squares of any pair of conjugate diameters is constant in a given ellipse.

PCP′, DCD′ are any pair of conjugate diameters of a given ellipse. If Q be the middle point of PD, find the locus of Q, and show that the area of the parallelogram PDP′D′ is constant. (40.)

29. Find the relations which must exist among the arbitrary constants in order that the equation—

$$ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$$

may represent (1) a circle;

(2) a pair of straight lines at right angles,

the axes of co-ordinates being rectangular.

Sketch the locus of the equation—

$$6x^2 - 5y^2 - 7xy - 4x + 11y = 2,$$

referred to oblique axes inclined to each other at 30°. (40.)

30. Find an expression for the cosine of the angle between two straight lines which make angles α, β, γ and α', β', γ' with the axes of rectangular co-ordinates.

What are the conditions which must be fulfilled in order that the straight lines

$$\frac{x-a}{A} = \frac{y-b}{B} = \frac{z-c}{C} \text{ and } \frac{x-a'}{A'} = \frac{y-b'}{B'} = \frac{z-c'}{C'}$$

may be (1) parallel, (2) at right angles to each other? (35.)

31. A plane passes through the points (1, 2, 3,) (−1, 2, 0) (2, −1, −1) the axes of co-ordinates being rectangular: find the equation of the plane, and the area of the triangle included by its lines of intersection with the co-ordinate planes: also find the co-ordinates of the foot of the perpendicular let fall on this plane from the origin. (35.)

32. Prove that the shortest distance between two straight lines which do not lie in the same plane is perpendicular to each of them.

Find the equation of the line on which lies the shortest distance between the lines

$$\left.\begin{array}{r} x - y + 2z = 2 \\ 2x + 3y - z = 1 \end{array}\right\} \text{and } x = y - 3 = 2z + 1.$$

Find also the shortest distance between them. (40.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Fourth Stage paper.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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41. Find the general equation of a conic section which passes through the four given points $(1, 1)$ $(-1, 1)$ $(2, 0)$ $(3, -4)$. Show that there are two parabolas which fulfil this condition. What is the nature of that conic through the four points which also passes through the origin? (60.)

42. Prove that the equation to the nine-points circle of the fundamental triangle can be written in the form

$$\frac{a^2}{b\beta + c\gamma - a\alpha} + \frac{b^2}{c\gamma + a\alpha - b\beta} + \frac{c^2}{a\alpha + b\beta - c\gamma} = 0.$$

(60.)

43. Pairs of tangents are drawn to a conic such that the sum of their inclinations to the transverse axis is a right angle. Prove that the locus of the point of intersection of these pairs of tangents is in general a rectangular hyperbola, passing through the focus of the conic. (50.)

44. If a rectangle circumscribe a given ellipse, and if PQRT is the figure formed by joining the points of contact; show that PQ and RQ are equally inclined to any side of the rectangle, and also that the sum of PQ and QR is constant for all positions of the rectangle. (60.)

45. What is the condition that must be satisfied in order that the pair of lines represented by the equation $ax^2 + bxy + cy^2 = 0$ may form a harmonic pencil with the lines $a'x^2 + b'xy + c'y^2 = 0$?

The common chord of two equal circles is a side of a regular inscribed hexagon: find the locus of a point P which moves in such a manner that the two pairs of tangents from P to the given circles form a harmonic pencil. (65.)

46. Construct by descriptive geometry a rectangular parallelopiped, having given the projections of a line through its centre joining opposite corners, and also that one pair of its faces is parallel to the vertical plane, and another pair parallel to the horizontal plane, of projection.

Find the projections of the circumscribing sphere, and of the sections made by a plane, through the centre, at right angles to the given diagonal. (60.)

47. Find the maximum number of double points which a curve of the nth degree can possess, when it does not resolve into curves of lower dimensions; and show that, if a curve has its maximum number of double points, the coordinates of any point on the curve can be expressed as rational algebraical functions of a variable parameter. (65.)

48. Find the general form of the equation to a cone on which lie the three lines of intersection of the co-ordinate planes.

PA, PB, PC are three straight lines at right angles to one another, and P moves in such a manner that PA, PB, PC always touch the surface—

$$ax^2 + by^2 + cz^2 = 1.$$

Find the equation of the locus of P. (65.)

49. Show that the sections of a quadric made by parallel planes are similar.

Find the axes of the section of the quadric—

$$a^2x^2 + b^2y^2 - c^2z^2 = 1 \text{ by the plane } Ax + By + Cz + D = 0.$$

(60.)

50. A and B are points on the surface of the earth, which is treated as a sphere of radius R. Small circles, whose angular radii are α, β respectively, are described about A and B as poles. Having given the latitudes λ, λ', and the longitudes l, l', of A and B, find the area of the spherical surface common to the two circles. (65.)

SUBJECT V. PURE MATHEMATICS, STAGES 6 & 7.

EXAMINER, P. T. WRIGLEY, ESQ., M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Sixth Stage, or from the Seventh Stage, or from the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Sixth Stage.—Subjects: Differential Calculus and Integral Calculus.

INSTRUCTIONS.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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1. Define a differential coefficient, and give a geometrical illustration. Deduce from first principles the differential coefficients with respect to x of the following functions:—

$$\cos ax, \qquad \tan^{-1} cx, \qquad \frac{x^2+ax+b}{x^2+ax-b}. \qquad (30.)$$

2. Establish the rule for differentiating a function of a function. Find $\frac{du}{dx}$ in the following cases:—

$$(1.) \quad u = \log\left\{\tan^3\left(\frac{\pi}{4}+x\right)\right\}.$$

$$(2.) \quad u = \left\{\frac{x}{1-\sqrt{1-x^2}}\right\}^m.$$

$$(3.) \quad u = a^{3x^2}\cos^{-1}\frac{2x^2+1}{2x^2+3}. \qquad (30.)$$

3. Give an expression for the remainder after n terms in the expansion of $f(x)$ by Maclaurin's theorem. Expand $\cos ax$ by Maclaurin's theorem, and show that the series is convergent.

   Find the coefficient of x^7 in the expansion of

$$\log\{\sqrt{1 + x^2} - x\}. \qquad (35.)$$

4. Explain fully how to find the limiting value of $\{\phi(x)\}^{f(x)}$ when x has a value c which makes $\phi(x)$ infinite, and $f(x)$ zero.

   Find the limiting values of $(x \log x)$ and of $(x \log x)^x$, when $x = 0$. (35.)

5. Show how to find the maxima and minima values of $f(x)$, and how to discriminate between them.

   At one of the foci of a level elliptical enclosure, whose semi-axes are 30 feet and 50 feet respectively, stands a flagstaff 60 feet high, whose upper third is painted white. Find two points in the major axis, one on each side of the flagstaff, at which the white portion subtends the greatest angle, the eye of the observer being at a height of $5\frac{1}{2}$ feet above the level of the enclosure.

   Find also the points on the minor axis where the maximum angle is subtended. (40.)

6. Give a method of tracing a curve systematically from its equation.

   Trace the following curves:—

$$x^2y = y - 2a.$$
$$r = u\,(\sec\theta - \cos\theta). \qquad (35.)$$

7. Obtain the following indefinite integrals:—

$$\int\frac{dx}{\sqrt{a^2x^2 - x^4}}. \qquad \int\frac{dx}{\sin^2 x - \cos^2 x}. \qquad \int\frac{dx}{x\sqrt{1 - x^3}}.$$

(35.)

8. Explain what is meant by a definite integral, and prove that if $\frac{d(f(x))}{dx} = \phi(x)$, then the definite integral of $\phi(x)dx$ between the limits x_1 and x_2 is $f(x_2) - f(x_1)$.

   Find the value of $\int_0^2 \frac{\sqrt{5 - 2x}}{1+2x}dx$. (30.)

9. What is meant by a formula of reduction?

   Give a formula of reduction for $\int \sin^n x \cos^m x\, dx$, and show that $\int_0^{r\pi} \sin^{14}\theta \cos^8\theta\, d\theta = \frac{91\pi r}{2^{19}}$. (35.)

10. Show how to find the area of a curve when its equation is given (1) in rectangular co-ordinates, (2) in polar co-ordinates.

Find the whole area of the curve whose equation is $x^4 + y^4 + a^2(x^2 - y^2) = 0$. (40.)

11. Find the perimeter of the figure enclosed by the two curves $ay^2 = x^3$, and $x^2 = 4ay$.

Find also the area enclosed. (40.)

12. Find the area of the surface generated by the revolution about an asymptote of the arc of the hyperbola $x^2 - y^2 = a^2$ cut off by the latus rectum. (40.)

Seventh Stage.—Subjects: Differential Calculus, Integral Calculus, Differential Equations, and Finite Differences.

INSTRUCTIONS.

Read the General Instructions at the head of the Sixth Stage paper.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions are shown in brackets.

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21. Having given $y = \phi\{z + xf(y)\}$, where x and z are independent variables, establish Laplace's theorem for the expansion of $F(y)$ in a series of ascending powers of x.

Deduce the expansion of $\cos 2y$ in powers of x, having given $y = z - x.\cos y$. (45.)

22. In the equation $x^2 \dfrac{d^2u}{dy^2} - 2xy \dfrac{d^2u}{dxdy} + y^2 \dfrac{d^2u}{dx^2} = 0$ change the independent variables from x, y, to z, θ, where $x = \dfrac{c \sin \theta}{e^z}$, $y = \dfrac{c \cos \theta}{e^z}$. (50)

23. P is any point within a given closed oval curve: show that the difference in area between the pedal of the curve and the pedal of its evolute, in each case with respect to P, is equal to the area enclosed by the given curve. (45.)

24. Show that $\displaystyle\int_0^\infty \frac{x^{2m}}{1 + x^{2n}}\,dx = \frac{\pi}{2n \sin \dfrac{2m+1}{2n}\pi}$, where m and n

are positive integers, and m less than n; and deduce that

$$\Gamma(n)\Gamma(1-n) = \frac{\pi}{\sin n\pi}. \qquad (55.)$$

25. Find the area of that portion of the surface of the sphere $x^2 + y^2 + z^2 = 2cz$ which is intercepted by the cone $z^2 = a^2x^2 + b^2y^2$. (50.)

26. If $f(x, y)$ and $\phi(x, y)$ are one-valued functions, show that the equation

$$f(x, y)\frac{dy}{dx} - \phi(x, y) = 0$$

can have only one independent primitive,

Solve the following equations:—

$$(1.)\quad \frac{dy}{dx} = \frac{y^2}{x\left(y - \sqrt{\dfrac{2x^2 - 3y^2}{3}}\right)}.$$

$$(2.)\quad \frac{dy}{dx} = \frac{xy^3}{xy + c^2}. \qquad (45.)$$

27. Show that the complete solution of a linear differential equation consists of a particular integral and a complementary function. How many arbitrary constants appear in the solution?

Solve the equation—

$$\frac{d^4y}{dx^4} - 5\frac{d^3y}{dx^3} + 6\frac{d^2y}{dx^2} + 4\frac{dy}{dx} - 8y = x^3. \qquad (50).$$

28. Solve the following simultaneous differential equations:—

$$(1.)\quad \left.\begin{aligned} \frac{dx}{dt} + 4x + 3y &= t \\ \frac{dy}{dt} + 2x + 5y &= e^t \end{aligned}\right\}.$$

$$(2.)\quad \left.\begin{aligned} \frac{d^2x}{dz^2} - 3x - 6y + 3 &= 0 \\ 3\frac{d^2y}{dz^2} + 2x - 24y + 14 &= 0 \end{aligned}\right\} \quad (45.)$$

29. Show how to solve the partial differential equation of the first order $\phi(p, q) = 0$ in which the variables do not explicitly occur. Solve $p^2 + q^2 = 5pq$, and give the geometrical interpretation. (55.)

30. Define the symbol of operation, E, in Finite Differences, and show that it obeys the three fundamental laws of Algebra: hence show that

$$\Delta^n u_x = u_{x+n} - n u_{x+n-1} + \frac{n\,.\,(n-1)}{1\,.\,2} u_{x+n-2} - \ldots + (-1)^n u_x.$$

Find $\Delta^2 \tan^{-1} \frac{x}{a}$, and $\Delta^5 \cos(ax + b)$. (50.)

31. Explain what is meant by the successive differences of zero.

Prove that

$$\phi(x) = \phi(0) + \phi(1 + \Delta)0\,.\log x + \phi(1 + \Delta)0^2\,.\frac{(\log x)^2}{1\,.\,2} + \ldots$$

(45.)

32. Show how to perform the finite integration of a rational integral function of x.

Find the sum of n terms of each of the following series:—

$$3\,.\,4\,.\,6\,.\,8 + 4\,.\,5\,.\,7\,.\,9 + 5\,.\,6\,.\,8\,.\,10 + \ldots\ldots$$

$$\frac{17}{3\,.\,4}\cdot\frac{1}{5} + \frac{21}{4\,.\,5}\cdot\frac{1}{5^2} + \frac{25}{5\,.\,6}\cdot\frac{1}{5^3} + \ldots\ldots$$ (45.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions, and may select them from any part of the paper.

The values attached to the questions differ but little from one another.

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41. Transform $\int_0^a\int_0^b \phi(x, y)\, dx\, dy$ into a double integral having u and v as the independent variables, where

$$x + y = u, \qquad y = uv.$$

42. Upon two intersecting straight lines as axes equal circular cylinders are described; show that the volume common to

the two cylinders equals that of a cone whose height is the diameter of either cylinder, and whose base has an area equal to that portion of the surface of either cylinder which lies inside the other.

43. Apply the Calculus of Variations to show that a circle is the curve of maximum area with a given perimeter.

44. Find the values of the definite integrals

$$\int_0^\infty \frac{\tan^{-1} ax}{x(1+x^2)}\,dx, \qquad \int_0^\pi x \log(\sin x)\,dx, \qquad \int_0^{2\pi} x \log(\sin^2 x)\,dx.$$

45. Establish the condition which must be satisfied if the surface $\phi(x, y, z,) = 0$ is developable. Test whether the following surfaces are developable or not:—

(1.) $xyz = a^3$. (2.) $xy - (z - c)^2 = 0$.

46. Having given a circle and an involute thereof, find the curve described by the centre of the circle when the involute rolls on a fixed straight line.

47. Solve the differential equation

$$\frac{d^2y}{dx^2} + \frac{2}{x}\frac{dy}{dx} + ay = 0.$$

48. Show that the complete solution of a partial differential equation of the first order, containing two independent variables, consists of a single complete primitive with its accompanying general integrals and singular solution.

49. Integrate the following partial differential equations:—

(1.) $x^2p^2 + y^2q^2 = 4xypq$.

(2.) $z = px + qy - sxy$.

50. Integrate the equations of differences—

(1.) $u_{x+3} - 3u_{x+1} + 2u_x = x;$

(2.) $$\left.\begin{aligned} u_{x+1} + 2v_{x+1} - 2u_x &= 0; \\ v_{x+1} - u_x + v_x &= a^x. \end{aligned}\right\}$$

SUBJECT VI. THEORETICAL MECHANICS.

EXAMINER, REV. J. F. TWISDEN, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, your papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than SEVEN QUESTIONS. You may select them from any part of the paper.

1. A lamina of uniform density is in shape a parallelogram; where is its centre of gravity situated?
   If the lamina weighs 4 lbs. and a particle weighing 1 lb. is placed at an angular point, where is the centre of gravity of the whole situated? (10.)
2. Draw a triangle ABC, whose sides BC, CA, AB are 7, 9, 11 units long. If ABC is the triangle for three forces in equilibrium at a point P, and if the force corresponding to the side BC is a force of 21 lbs., show in a diagram how the forces act, and find the magnitude of the other two forces. (12.)
3. A straight line AB represents a rod 10 ft. long, supported horizontally on two points—one under each end; C is a point in AB, 3 ft. from A; what pressure is produced on the points A and B by a weight of 30 lbs., hung at C? What additional pressure is exerted on the points of

support, if the rod is of uniform density and weighs 20 lbs.? (14.)

4. Define the moment of a force with reference to a point. When is a moment reckoned positive and when negative? Draw an equilateral triangle ABC, and suppose each side to be 4 ft. long; a force of 8 units acts from A to B, and a force of 10 units from C to A. (*a.*) Find the moment of each force with reference to the middle point of BC; (*b.*) Find a point with reference to which the forces have equal moments of opposite signs. (18.)

5. A number of men can each do, on the average, 495,000 foot-pounds of work per day of eight hours; how many of such men are required to do work at the rate of 10 horse-power? (8.)

6. The radius of a circle is half a mile; a horse runs round the circumference at the rate of five times an hour; what is his velocity in feet per second? (The result should be carried to the second decimal place.) (8.)

7. Given the formula $s = \frac{1}{2}ft^2$, state the meaning of each letter in it. If the formula is to be applied to the case of a falling body, and f is given equal to 32·19 or (approximately) 32, what supposition is implied as to units of time and distance? (10.)

8. A body weighing 100 lbs. is observed to be moving at the rate of 20 ft. a second; assuming that it began to move from a state of rest, and that its motion was impeded by no resistance, how many units of work must have been done on it by the force that gave it the velocity? Give the answers (*a*) in foot-poundals, (*b*) in foot-pounds, assuming $g = 32$. (12.)

9. Two bodies, whose velocities are accelerated in every second by 3 and 5 ft. a second respectively, begin to move towards each other at the same instant, and without having any initial velocity; at first they are a mile apart; after how many seconds will they meet? (16.)

10. Two small areas (A and B) are marked on a vertical wall of a reservoir; the area of A is twice that of B, and A is 10 ft. above B; if water is let into the reservoir, what will be the height of its surface above A, when the pressure of the water on A is one-fourth of its pressure on B? (14.)

11. If 28 cubic inches of water weigh a pound, what will be the specific gravity of a substance, 20 cubic inches of which weigh 3 lbs.? (8.)

12. Describe the forcing-pump.

When the piston (or plunger) is raised why does the water come into the barrel of the pump? (14.)

Second Stage or Advanced Examination.

Instructions.

Read the General Instructions on the first page.

You are not permitted to attempt more than *eight* questions. You may select them from any part of the paper.

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21. Assuming the rule for finding the centre of gravity of a triangular pyramid; prove the rule for finding that of a pyramid whose base is a four-sided figure. (15.)

22. Show that the moments of two intersecting forces, with respect to a point in the line along which their resultant acts, are equal and of opposite signs. (15.)

23. Forces P, Q, R act along the sides of a triangle, ABC, from B to C, C to A, and A to B, and are proportional to the lengths of the sides along which they act; (*a*) show that they form a couple, and find its moment; (*b*) find their resultant, when the direction of one of them (P) is reversed. (25.)

24. A cube is placed with one edge on a rough horizontal plane (coefficient of friction $= \mu$), and a parallel edge on a smooth plane, inclined at an angle of 45° to the horizon; if θ is the inclination of the base of the cube, when in the position in which it will just not slide into a lower position, show that $(1 + 3\mu) \tan \theta = 1 - \mu$. (30.)

25. Define the centre of a system of parallel forces, and state a method of finding the co-ordinates of its position when there are more than two forces. Apply the method to the following case:—ABCD is a square, and AC a diagonal; forces P, Q, R act along parallel lines at B, C, D respectively, Q acts in the direction A to C, P and R act in the opposite direction; find, and show in a diagram, the position of the centre when $Q = 5P$ and $R = 7P$. (25.)

26. Two weights, P and Q, hang by a flexible thread over a fixed pulley, capable of turning on a rough axle; find the relation between them, when P is on the point of preponderance.

    If the radii of the pulley and axle, are 10 in. and 1 in., and if a weight of 101 lbs. will just preponderate over a weight of 99 lbs.; find the coefficient of friction between the axle and its bearing. (25.)

27. Find the number of foot pounds of work required to wind up a given chain, which hangs by one end. (15.)

28. A particle describes the perimeter of a regular hexagon with a constant velocity of 100 ft. a second; find the magnitude and direction of the velocity that must be communicated to it, at the instant it reaches an angular point. (20.)

29. Investigate the time of a small oscillation of a simple pendulum.

A seconds pendulum has its length slightly altered, and, in consequence, loses n seconds a day; find whether it has been lengthened or shortened, and by what fraction of its original length. (25.)

30. Find the moment of inertia of a circular lamina of uniform density, with reference to an axis through its centre at right angles to its plane.

If the mass of the lamina is 100 lbs., and its diameter $3\frac{1}{2}$ ft., and if it turns round the axis 120 times a minute, find its kinetic energy (*a*) in foot-poundals; (*b*) in foot-pounds ($\pi = 3\frac{1}{7}$, $g = 32$). (30.)

31. Find the conditions of equilibrium of a solid body floating in liquid and partly supported by a string. (15.)

32. State and prove Torricelli's theorem.

A reservoir is kept full, so that the surface of the water is at a constant height of 12 ft. above a small hole, the effective area of whose cross section is $\sqrt{3}$ square inches; find how many cubic feet of water flow out in an hour ($g = 32$). (20.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on the first page.

You are not permitted to attempt more than *eight* questions. You may select them from any part of the paper.

41. ABCDEF is a piece of wire of uniform density, bent into the form of the perimeter of a regular hexagon; if the side AF is cut away, and the remainder hung up by the point A, show that the cosine of the inclination of AB to the vertical is $\frac{13}{2\sqrt{133}}$. (50.)

42. Forces act in the plane of a rigid polygon, at the middle points of the sides, and at right angles to them; show that they are in equilibrum, if they all act inwards and are proportional to the lengths of the sides on which they act. (40.)

43. ABC is a triangular frame, whose weight can be neglected; it is hung up by the point A, and weights (W and w) are

hung at B and C; find the stresses in the bars, AB, BC, CA. (60.)

44. AB, a beam of uniform weight per unit of length, is supported horizontally on two points, one under each end; a weight is hung on it from a point P, nearer to A than to B; find (*a*) the bending moment at any point between P and B, (*b*) the position of the point at which the bending moment is greatest, and (*c*) the circumstances under which the bending moment will be greatest at P. (50.)

45. A string is stretched on the circumference of a rough circle; when one of the forces is on the point of preponderance, find the pressure on the circumference, and the tension o the string, at any assigned point. (50.)

46. Calculate the value of $\Sigma(mxy)$ in the case of a piece of wire of uniform density, bent into the form of the perimeter of a rectangle, a diagonal being taken as the axis of x. (50.)

47. A and B are two points in a horizontal line, 4 ft. apart; a body is fastened to one end of an inextensible string 10 ft. long, the other end being fastened to a fixed point at A; the body is placed at B and allowed to fall; find its velocity immediately before and immediately after the string is drawn straight. (40.)

48. A particle slides down a smooth inclined plane and passes without loss of velocity on to a rough horizontal plane; it comes to rest after describing a distance on the horizontal plane, equal to the distance it had described on the inclined plane; find the coefficient of friction between the particle and the horizontal plane, and the whole time of the motion. (40.)

49. A lamina moves in its own plane in such a way that a point in it (C) has a velocity (V) along a straight line CD, while the lamina revolves round C with a given angular velocity (ω); two points, A and B, are taken in the lamina, such that the line AB is bisected by C; compare the kinetic energies of two particles, forming part of the lamina, and placed one at A and the other at B. (50.)

50. Describe briefly the ballistic pendulum, and investigate a formula for the velocity of a shot fired into it. (50.)

51. Explain how to find, by the balance, the specific gravity of an insoluble solid lighter than water. (40.)

52. The tenacity of copper being given as 40,000 lbs. per square inch; find the bursting pressure, in pounds per square inch, of a hollow copper globe 2 ft. in diameter and a quarter of an inch thick. (40.)

SUBJECT VII. APPLIED MECHANICS.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You may not attempt *more than six* questions.

The value attached to each question is shown in brackets after the question.

1. How is the work done by a force measured? Give some example. Set out a diagram of the work done in drawing a body weighing 10 lbs. up a smooth incline 4 feet high, marking dimensions. (12.)
2. What is a surface plate? How is it constructed and used? Of what material is it made, and for what reason? Describe, with sketches, the tools employed. Why is it essential that the plate should rest on three supports? (12.)
3. Under what conditions will two cones roll together? Motion is to be communicated between two shafts inclined at an angle of 90°, and one is to make three rotations while the other makes four. Set out the pitch cones in a diagram, marking dimensions. (15.)
4. In a 30-ton crane the tension of the chain as it runs on the winding barrel is 7½ tons, the barrel is 2 feet in effective diameter, and the spur wheel connected with it is 4 feet in diameter on the pitch line; what pressure will come

upon the teeth of the spur wheel, supposing such pressure to act on the pitch line? (Friction is neglected.) (15.)

5. Describe, with sketches, the construction of an ordinary lifting jack in which the weight is lifted by means of a screw and nut. If the screw be 1 inch pitch, the lever 20 inches long, and the pressure applied at the end of the lever be 30 lbs., what weight can be lifted (neglecting friction)? (Take $\pi = 3{\cdot}1416$.) (15.)

6. A barrel weighing 5 cwt. is lowered into a cellar down a smooth slide inclined at an angle of 45° with the vertical. It is lowered by means of two ropes passing under the barrel, one end of each rope being fixed, while two men pay out the other ends of the ropes. What pull in pounds must each man exert in order that the barrel may be supported at any point? (15.)

7. What is the meaning of the term *ductility* as applied to wrought iron? Describe, with sketches, some apparatus for testing a piece of metal as to ductility. If a uniform bar of iron 10 inches long is found to stretch $1\frac{1}{2}$ inches at the time of fracture, what is the measure of the ductility of the material of the bar? (20.)

8. Find the extension produced in a bar of wrought iron 4 feet long and 2 square inches in section by a suspended weight of $4\frac{5}{6}$ tons, the modulus of elasticity of the material being 29,000,000 pounds per square inch. (15.)

9. How is the coefficient of friction between two surfaces ascertained approximately by experiment?

   When two rough surfaces are pressed together, how much may the line of pressure be inclined to the common perpendicular to the surfaces in contact before motion ensues? (15.)

10. A cylindrical vessel 30 inches long and 6 inches in diameter is sunk vertically in water, so that the base, which is horizontal, is at a depth of 25 inches below the surface of the water. Find the upward pressure in pounds on the base of the vessel. The weight of a cubic foot of water is $62\frac{1}{2}$ lbs., and $\pi = 3{\cdot}1416$. (15.)

11. Sketch and describe the mechanism for cutting a screw with five threads to the inch in a lathe where the guide screw has three threads to the inch. Assign suitable numbers to the wheels which you would employ. (20.)

12. An hydraulic accumulator, with a ram of 16 inches in diameter, is connected with an hydraulic press whose ram is 26 inches in diameter. The load on the accumulator is 80 tons; what power would the press exert? Make a vertical section through the accumulator, showing its construction. (15.)

13. Two wooden beams are each loaded in the centre and supported at the ends; one is solid and measures 8″ × 8″ in cross section; the other is made up of two beams, each 8″ broad and 4″ deep, and placed one over the other so as to have the same sectional area as before. Will there be any difference in the breaking load of the beams, and if so how much will it be? State the reasoning on which you rely. (20.)

14. Describe a simple form of a counting or numbering machine for registering successive numbers up to 99, the machine being actuated by a vibrating lever arm. (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

21. A ship is moored by two cables of 90 feet and 100 feet in length respectively. The first cable stretches 2⅝ inches, and the second stretches 3 inches, under the pull of the ship; find the strain of each cable. (15.)

22. The travel of the table of a planing machine cutting both ways is 9 feet, and the resistance to be overcome while cutting is taken at 400 lbs. If the number of double strokes made in one hour be 40, find the horse-power absorbed by the machine. (30.)

23. The head of a steam hammer weighs 10 cwt., and has a fall of 8 feet. If it indent the iron on which it falls by 1 inch, find the mean force exerted on the iron during compression. (25.)

24. Sketch and describe the screw lifting jack as fitted with screw and worm wheel gear. The handle being 15 inches long, the pitch of the screw 1¼ inches, and the worm wheel having 15 teeth, find the force on the handle for raising 5 tons. (Friction is neglected). (25.)

25. Show clearly by the aid of sketches the mechanism employed in a shearing machine for converting the continuous circular motion of the driving shaft into the vertical reciprocating motion of the upper cutting edge. Show also an arrangement by which the upper blade can be kept stationary while the driving shaft continues to revolve. (25.)

26. A pump for exhausting air from a receiver has a solid piston and one valve in the casing. Describe, with a sketch, the construction of the pump, and explain the nature of the improved form known as Sprengel's pump, where a small portion of mercury forms the piston and no valve is required. (25.)

27. A tripod whose vertex is A, and whose legs are AB, AC, AD, of lengths 8, 9, and 10 feet respectively, sustains a load of 2 tons. The ends B, C, D form a triangle, whose sides are BC = 7 feet, CD = 6 feet, BD = 8 feet, find by graphical construction the compressive stress in each leg. (35.)

28. Describe, with sketches, some form of hydraulic lift, and the manner in which it is worked. (35.)

29. What is the principle of a dead-beat escapement? Show, with sketches, the mode of applying this principle in an ordinary lever watch. (30.)

30. Prove the formula which gives the velocity of rotation of the last wheel of an epicyclic train in terms of the velocities of the first wheel and the arm, and arrange an epicyclic train in which the last wheel and the arm shall rotate with equal velocities in opposite directions. (30.)

31. Describe, with a sketch, a method of employing friction rollers or spheres for causing a wheel to be locked to an axis when turning in one direction, but allowing it to run free when the rotation is reversed. (30.)

32. A triangular frame is at rest under the action of 3 external forces: prove that a certain diagram will represent the stresses in the bars of the frame. Extend this proposition to the case of a lattice girder of the Warren construction, with 4 bays in the lower boom and 3 bays in the upper boom, loaded in the centre of the lower boom and supported at the ends, giving the stress diagram and showing how to distinguish the portions which are in compression or extension. (35.)

33. A segment of a fly wheel with the arm to which it is attached weighs 3,500 lbs., and the mass of the portion may be taken as collected at a distance of 8 feet from the axis of the wheel, which makes 40 revolutions per minute. What is the force tending to pull away the segment and arm from the boss of the wheel? You are required to write out a proof of the formula which you employ. (35.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You may not attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

41. In the older saw frames a ratchet was employed to move the timber for each cut, but in modern frames the ratchet teeth are dispensed with, and an arrangement depending on a frictional grip adjustable to any rate of feed motion is substituted. Sketch and describe the contrivance by which this object can be effected, and explain the principle of its action. (60.)

42. A twisting moment of 9,600 inch-pounds is sufficient to break a wrought-iron shaft of 1 inch diameter. Use 6 as a factor of safety, and hence determine what horse-power can be safely transmitted through a shaft of 3-inch diameter when running at 120 revolutions per minute. Prove the formula which you employ. (60.)

43. If CP be the crank, and PQ the piston rod in an oscillating engine, find the velocity ratio of P to Q and set out the result in a diagram. Find also the angular velocity ratio of CP and PQ at any part of the stroke. (60.)

44. A planing machine for metals is driven by a rack and pinion with other gearing between the driving pulley and the pinion. The driving pulley makes 80 revolutions per minute, and the pinion wheel gearing into the rack on the under side of the table has 12 teeth of 1½-inch pitch. The table makes its cutting stroke at the rate of 12 feet per minute, and its return stroke at 24 feet per minute. Sketch the arrangement and calculate the number of teeth in the several wheels of the mechanism. (65.)

45. The internal diameter of an hydraulic cylinder is 8 inches, and the ultimate tensile strength of the material of which it is made is 16,000 lbs. per sq. inch. What thickness of metal would be required in the sides of such a cylinder, if the metal be not stressed beyond one-sixth of its ultimate strength, the water being under a pressure of 2,000 lbs. per sq. inch? Prove the formula which you employ. (80.)

46. Describe the construction of the Whitworth measuring machine for measuring to one ten-thousandth of an inch

in end measure. Make such sectional or other sketches as may be necessary. A standard gauge 1 inch in diameter being supplied, describe the process of forming a second gauge of 1·001 inches in diameter. (50.)

47. In forming the teeth of wheels, the geometrical condition is that the common perpendicular to the surfaces of two teeth in contact shall always pass through the point of contact of the pitch circles of the wheels. Write out a proof of this general proposition. (65.)

48. Describe the construction of an intensifying accumulator whereby a pressure of water of (say) 60 lbs. per square inch may be increased up to 1,500 lbs. per square inch on the ram. Sketch a longitudinal section through the apparatus, showing the mode of packing the working parts. (50.)

49. In a travelling crane of 40 feet span the load is supported on a carriage which runs upon two similar girders, the axles of the carriage being 8 feet apart, and a load of 2½ tons coming upon each wheel. Obtain a diagram showing the maximum bending moment at every section of the girder, and give the numerical values at distances of 10, 15, and 20 feet from one end. (70.)

SUBJECT VIII. SOUND, LIGHT, AND HEAT.

EXAMINERS:

PROFESSOR W. GRYLLS ADAMS, M.A., D.Sc., F.R.S.,

AND

PROFESSOR OLIVER J. LODGE, D.Sc., LL.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *eight* questions. These may be selected from any part of the paper.

The value attached to each question is the same.

Sound.

1. State how the air moves in different parts of a tube 1 foot long, open at both ends, when sounding its fundamental note. What note does it give?

2. A glass rod 5 feet long is clamped at its centre, and rubbed longitudinally with a wet cloth. State how it vibrates when thus treated, and calculate the velocity of sound in glass, if told that the above rod makes 1,295 complete vibrations every second.

3. Explain the character of the vibration of a stretched violin string. What effect is produced by touching it at one-third of its length from one end?

4. Sketch the essential parts of an air-pump. If the receiver is 12 times as large as the pump barrel, what is the pressure of the air left in it after two strokes of the pump, in terms of the original pressure?

Light.

5. When a horizontal beam of light falls on a vertical plane mirror which revolves about a vertical axis in its plane, show that the reflected beam revolves at twice the rate of the mirror.

6. Describe an experiment proving that white light is compound. How can it be shown that the constituents into which it is resolved are not likewise compound?

7. Explain the apparent bending of a stick when dipped into water, stating broadly from experience the most favourable conditions for observing the effect.

8. A source of light is seen by reflection in two vertical plane mirrors placed against the two walls in a corner of a square room. Construct a figure showing exactly the path of a beam which enters the eye of an observer after two reflections, one at each mirror.

Heat.

9. Describe some form of maximum and of minimum thermometer explaining how they act.

10. What is meant by a *unit of heat?* Taking the specific heat of lead as 0·031, and its latent heat as 5·07, find the amount of heat necessary to raise 15 lbs. of lead from a temperature of 115° C. to its melting point, 320° C., and to melt it.

11. Describe an instrument for accurately determining the dew-point. What do you understand by the term?

12. Should a kettle intended to be heated by standing in front of a fire be bright or black? State fully the reasons for your answer.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions. These may be selected from any part of the paper.

The value attached to each question is the same.

Sound.

21. Explain and illustrate the mode of vibration of air. Taking 1,120 feet per second as the velocity of sound in air, find the number of vibrations which a middle C tuning fork giving 256 vibrations per second will make before its sound is audible at a distance of 154 feet.

22. If a string 24 inches long weighs half an ounce, and is stretched with a weight of 81 lbs., find its rate of vibration when bowed or struck.

23. Given a set of standard tuning forks, how can you determine accurately the rate of vibration of any sounding body?

24. State the modes of vibration possible to bells, and how you would illustrate them.

Light.

25. Show how to determine, either graphically or arithmetically, the position and magnitude of the image of an object placed in front of a convex lens. An arrow 5 inches long is placed 8 inches away from a convex lens whose focal length is 3 inches. Find the position and length of the image.

26. Explain the apparent raising of a picture stuck at the bottom of a cube of glass, till it appears to an eye looking down as if it were in the glass. If the index of refraction is 1·8, how much does the picture appear raised to perpendicular vision?

27. Sketch the plan of a spectroscope, explaining the use of the collimator; and describe how to make a map of the spectrum of a given substance.

28. A beam of white light proceeding from a narrow slit is thrown by means of a lens on to a screen. Explain the appearance which would be produced by the placing of a diffraction grating between the lens and the screen in the path of the beam.

Heat.

29. Describe a mode of determining the specific heat of a solid. A mass of 700 grammes of copper at 98° C., put into 800 grammes of water at 15° C., contained in a copper vessel weighing 200 grammes, raises the temperature of the water to 21° C. Find the specific heat of copper.

30. Explain in what way the melting-points of bodies are affected by pressure. Illustrate your answer by reference to the case of water and wax.

31. What do you understand exactly by the efficiency of a steam engine? What is the theoretical efficiency of a steam engine whose boiler is at 150° C. and its condenser at 40°?

32. State concisely the characteristic properties of permanent gases, and sketch an apparatus for determining their coefficient of expansion at constant volume.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are expected to attempt all the questions.

The value attached to each question is the same.

41. If a quantity of air at 15° C. is suddenly compressed to half its volume, show how to calculate the temperature it will momentarily attain. Explain the importance of this knowledge in the theory of sound-propagation.

Show how a numerical answer can be given with the help of the following data:—

$$\log 2 = 0{\cdot}3010$$
$$\log 1{\cdot}32 = 0{\cdot}1204.]$$

42. Describe Newton's rings, as seen by reflection. What relations hold between the thickness of the air space, the diameters of the rings, and the angle of incidence of the light?

43. Describe the saccharimeter. Explain the mode of using it to determine the strength of a sugar solution. Mention different forms of analyser which may be used.

44. Explain how the thermal equivalent of mechanical energy may be derived from a knowledge of how much heat is required to warm a given quantity of gas a given number of degrees, first when the pressure on it is kept constant, and next when it is heated in a closed inexpansible vessel.

45. Describe the process of determining the coefficient of expansion of a liquid like alcohol or paraffin, remembering the necessary preliminary determination of the expansibility of the glass vessel employed.

Honours Practical Examination.

1. Time two tuning-forks to give 4 beats a second, stating which is the higher.

2. Arrange an experiment to shew that the velocity of Sound in a gas does not depend upon the density of the gas.

3. Compare the co-efficients of isothermal and adiabatic elasticity for the given wire corresponding to longitudinal stress.

4. Find by an optical method the curvatures of the faces of a lens.

5. Determine the index of refraction of the specimen of glass for sodium light.

6. Determine the magnifying power of a given lens by images formed by reflection at its surfaces.

. Determine the wave-lengths of three of the lines in the spectrum of the given substance.

8. Determine the relation between the strength of a sugar solution and the angle of rotation of the plane of polarization of a beam of polarized light passing through it.

9. Determine the water-equivalent of the given calorimeter.

10. Find the specific heat of a mixture of the two liquids.

11. Compare the vapour pressures at the temperature of the room of a mixture of 10 per cent. of sulphuric acid and 90 per cent. of water with that of distilled water.

SUBJECT IX. MAGNETISM AND ELECTRICITY.

Including Special Paper in Alternative Elementary Physics.

EXAMINERS, PROFESSOR A. W. REINOLD, F.R.S.,
AND PROFESSOR A. W. RÜCKER, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the paper in Alternative Elementary Physics, or the Elementary, or the Advanced, or the Honours Paper in Magnetism and Electricity, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

ALTERNATIVE ELEMENTARY PHYSICS.

INSTRUCTIONS.

Read the General Instructions on p. 1.

You are not permitted to attempt more than *eight* questions, and of these not more than *two* may be selected from any one subject.

The value attached to each question is the same.

Sound.

1. A gun is fired on a cold winter's day at a certain distance from an observer who hears the report five seconds after seeing the flash. Would the interval between seeing the flash and hearing the sound have been the same on a hot day in summer? Give reasons for your answer.

2. Describe an instrument by which the pitch of the notes emitted by two vibrating strings may be compared. If they were different, how would you attempt to bring them into unison?

Light.

3. What is meant by the law of inverse squares as applied to light? How is the law applied in comparing the intensities of two sources of light?

4. Describe and explain the difference of the effects observed when the sun sets over a smooth lake or sea, according as the water is (1) absolutely smooth, or (2) covered with ripples.

5. The shadow of a red-hot poker is cast on a white screen by means of a lime-light lantern. Explain the smoky appearance on the screen just above the shadow.

Heat.

6. To what reading on a Fahrenheit thermometer does 28° C. correspond? Why is it necessary to read the barometer when determining the boiling point of a thermometer?

7. How is the climate of the British Isles affected by the high capacity for heat of water?

8. Two copper balls of the same weight and raised to the same temperature, are laid, the one on a cake of slowly melting ice and the other on a cake of wax. The latter sinks in the more deeply. What inference would you draw from this?

Magnetism.

9. A rod of iron and a rod of steel are stroked in succession with one of the poles of a bar magnet. How do the iron and steel rods respectively affect a compass needle when brought near to it?

10. How do (1) a dipping needle, (2) a compass needle behave at the magnetic poles of the earth?

Frictional Electricity.

11. A certain substance becomes electrified when it is rubbed with a silk handkerchief. How would you determine whether its electrification is positive or negative?

12. A glass rod which has been rubbed with amalgamated silk is held near to an insulated metal ball, and the side of the ball nearest to the glass momentarily touched, after which the glass rod is removed. Describe and explain the effect of each step in the experiment.

13. Describe the construction of a simple form of electrical machine.

Voltaic Electricity.

14. A vertical wire, down which an electric current is flowing, is held (1) due east, (2) due south of a small compass needle. How is the needle affected in each case?

15. A delicate thermometer is immersed in dilute acid into which plates of zinc and copper are dipped. When the plates are connected by a copper wire, the temperature of the liquid rises. Why is this?

16. Give a general explanation of the method of sending a telegraphic message.

MAGNETISM AND ELECTRICITY.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions on p. 1.

You are not permitted to attempt more than *eight* questions.

You may select only *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

21. A bar of soft iron AB is placed horizontally east and west, the east end A being about 4 inches to the west of the north seeking pole of a compass needle. The end A being fixed, B is raised until the bar is vertical. How is the needle affected by the bar when in its original and final positions?

22. The beam of a balance is made of soft iron. When it is placed at right angles to the magnetic meridian two equal weights placed in the opposite pans just balance. Will the weights still appear to be equal when the balance is turned so that the beam swings in the magnetic meridian? Give reasons for your answer.

23. An iron ball is held over a pole of a horse-shoe magnet. Will the attraction exerted on the ball be altered if the poles of the magnet are connected by a soft iron keeper, and, if so, in what way, and why?

24. Three precisely similar magnets are placed vertically with their lower ends on a horizontal table. Iron filings are scattered over a plate of glass which rests on their upper ends, two of which are north poles and the third a south pole. Give a diagram showing the forms of the lines of force mapped out by the filings.

Frictional Electricity.

25. An electrified metal ball is introduced into a dry glass tube closed at one end, and then, the tube being held in the hand, is brought near to the cap of an electroscope. What will the effect on the electroscope be if the exterior of the tube (1) is, (2) is not, covered with tinfoil?

26. The extremity B of a wire AB is attached to the plate of a gold leaf electroscope. By means of an insulating handle, the other end A is placed in contact first with the blunt and then with the more pointed end of a pear-shaped insulated and electrified conductor.

    Describe and explain the movements of the leaves of the electroscope.

27. You charge a Leyden jar by holding its outer coating in the hand and bringing the knob to the prime conductor of an electrical machine. If you wished to charge the jar to as high a potential as possible, would you hold the knob in contact with the prime conductor, or keep them a small distance apart? Give reasons for your answer.

28. A muslin bag containing sulphur and red lead finely powdered is suspended by a silk ribbon so that it hangs within a metal vessel which stands on the cap of an electroscope. When the bag is jerked the powders are shaken out through the muslin into the vessel and become electrified by friction. State and explain what effect (if any) is produced upon the electroscope.

29. Sparks pass between the prime conductor of an electrical machine and a metal knob, connected with the earth, held near to it. Describe the changes, if any, in the phenomena observed, as the knob is gradually moved away from the prime conductor.

Voltaic Electricity.

30. A number of cells formed of plates of zinc and platinum, immersed in dilute sulphuric acid, are to be connected in

a circuit, so that the platinum of each cell is in contact with the zinc of the next. What effect, if any, would be produced on the current if, by mistake, one cell was made up with two platinums, instead of with one platinum and one zinc plate?

31. A wire lies east and west (magnetic) immediately over a compass-needle. How is the direction in which the needle points affected when a *strong* current flows through the wire (1) from west to east; (2) from east to west?

32. Why is an astatic galvanometer better adapted for the measurement of weak currents than a galvanometer with a single needle?

33. Two Grove's cells, alike in all respects except that in one the plates are twice as far apart as in the other, are arranged in series, and the poles of the battery so constituted are united by a copper wire. The liquid in both cells becomes heated. In which is the rise in temperature the greater, and why?

34. A gutta-percha covered copper wire is wound round a wooden cylinder AB from A to B. How would you wind it back from B to A (1) so as to increase, (2) so as to diminish the magnetic effects which it produces when a current is passed through it? Illustrate your answer by a diagram drawn on the assumption that you are looking at the end B.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on p. 1.

You are not permitted to attempt more than *eight* questions.

You may only select *two* in Magnetism, *three* in Frictional Electricity, and *three* in Voltaic Electricity.

The value attached to each question is the same.

Magnetism.

41. The north pole of one magnet and the south pole of another are placed in contact with one end of a rod of steel, and drawn to the other end, being prevented from touching each other by a piece of wood placed between them. Explain the magnetic state of the various parts of the steel rod at the moment when the piece of wood has reached its centre.

42. Two bar magnets, the moments of which are in the ratio 8 : 27, are placed with their centres 3 feet apart, their magnetic axes being in the same straight line, which is perpendicular to the magnetic meridian. If their north poles are turned towards each other, find the position which a small compass needle must occupy on the line joining the magnets in order that it may point in the same direction as if the magnets were not there.

43. A glass tube containing four similar pieces of hard steel which just fill it when placed end to end, is suspended so that it can oscillate about its central point in a horizontal plane. What will be the nature of the difference (if any) in the times of oscillation when (1) the two outer pieces only, (2) the two inner pieces only are magnetized, unlike poles being in both cases nearest together? Neglect the effects of induction, and give reasons for your answer.

44. Explain why, in determining the magnetic dip at any place, it is necessary to reverse the magnetism of the needle so as to make each end of it dip in turn.

Frictional Electricity.

45. Two equal insulated metal balls are placed near each other. One of them receives a charge of positive electricity. Show by a diagram the distribution of the lines of electric force in the neighbourhood of the balls.

46. Two insulated and widely separated metallic spheres receive charges of positive electricity which raise their potentials to 4 and 5 respectively. The densities of the charges being in the ratio 4 : 9, compare the radii of the balls.

47. Of two insulated metallic plates, A and B, which are placed near and parallel to each other, A is connected with the cap of an electroscope, and B receives a charge of electricity. Explain the behaviour of the gold leaves of the electroscope when a slab of unelectrified sulphur is introduced into the space between the plates.

48. A hollow metal vessel is insulated, connected by a wire with a gold leaf electroscope, and charged with electricity. The leaves diverge. An uncharged metal ball is lowered into the vessel without touching it, (1) by a silk thread, and (2) by a wire. What is the effect on the gold leaves in each case?

49. Describe the principal parts of a simple form of quadrant electrometer. What is the instrument designed to measure?

Voltaic Electricity.

50. A plate of zinc, and a plate of copper are in contact at one end. Their other ends are connected, (1) by a piece of platinum, (2) by a drop of dilute acid. Why does a current flow round the circuit in the second case and not in the first?

51. The terminals of a battery of five Grove's cells, the total electromotive force of which is 9 volts, are connected by three wires, the resistance of each of which is 9 ohms. The current through each wire is six-sevenths of an ampère. What is the internal resistance of each cell?

52. The poles of a cell are joined by two wires similar in all respects, except that one is longer than the other. In which is the greater amount of heat produced, and why?

53. A ring is made, partly of iron and partly of copper wire, the junctions being A and B. If A be kept at 0° and B at 100°, a thermo-electric current is produced in the circuit. Similarly a current is produced if A be at 100° and B at 200°. Have the currents in each case the same strength? Give reasons for your answer.

54. When a circular metallic hoop is rotated in the earth's magnetic field, electric currents are generally produced in it. In what positions of the axis of rotation will the induced currents be the greatest and least respectively? Give reasons for your answer.

Honours Examination.

Read the General Instructions on p. 1.

Full marks can only be got by answering all the questions.

61. Having given the horizontal intensity of the earth's magnetic field, give a detailed account of the construction of a tangent galvanometer by which the intensity of electric currents might be determined in absolute measure.

62. It is sometimes said that an electric current behaves as though it possessed *inertia*. Discuss this statement.

63. Discuss the evidence in favour of the view that the force in play between two electrical charges (each supposed concentrated at a point) varies inversely as the square of the distance between them.

64. Describe fully some method of determining the permeability of a magnetic substance.

65. Give an account of the British Association experiment for determining an electrical resistance in absolute measure. Show how, from the data of the experiment, the resistance of the coil used is obtained.

Honours Practical Examination.

Magnetism and Electricity.

1. Determine the intensity of the magnetisation of the magnet supplied to you.

N.B.—The intensity of the earth's magnetic field may be taken as 0·18 C.G.S. units.

2. Investigate whether any correction must be applied to measurements made with the metre bridge supplied to you for imperfect contact at the ends of the wire.

Use a method which will enable you to determine the error if it exists.

N.B.—You are supplied with two coils of which the resistances are known together with a mirror galvanometer, &c.

3. Determine the strength of the magnetic field in the laboratory by the method of induction.

4. Compare the resistances supplied to you by the condenser and ballistic galvanometer method.

5. Determine the specific resistance of the sample of mercury supplied to you.

N.B.—The sample has not been specially purified.

6. Compare the E.M.F. of two cells by the Quadrant Electrometer.

SUBJECT X. INORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or Alternative Elementary, or the Advanced, or the Honours paper; but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

H = 1. O = 16. Cl. = 35.5. N = 14.

1. A piece of marble is placed in dilute hydrochloric acid. Explain why it disappears, and state the change which the marble and the acid undergo. (9.)

2. By what experiments could you show that hydrogen was a constituent of hydrochloric acid, sulphuric acid, and ammonia? (13.)

3. What is a chemical equation? Give in the form of chemical equations the action of—

   (1.) Sulphuric acid upon common salt.
   (2.) Sulphuric acid upon copper when heated.
   (3.) Sulphuric acid upon an aqueous solution of ammonia. (10.)

4. By what tests could you prove that a substance which was stated to be sulphur actually was that element? (12.)

5. Describe fully experiments showing (1) the analysis of hydrochloric acid, and (2) the synthesis of hydrochloric acid. (13.)

6. How can sulphurous acid be converted into sulphuric acid, and how can sulphuric acid be converted into sulphurous acid? How could you distinguish a sulphite from a sulphate? (10.)

7. Name the substances having the following formulæ: H_2S; NH_3; CO; H_2CO_3; NO; NO_2; SO_3; O_3. (9.)

8. What weight of pure nitric acid would contain 100 grams of oxygen; and what weight of pure hydrochloric aicd would contain 100 litres of chlorine at the standard temperature and pressure? (15.)

9. How is sulphuretted hydrogen made? Describe its chief properties, and state how you could prove that it contained its own volume of hydrogen? (13.)

10. What weight of oxygen is required to burn 16 grams of hydrogen to water, and what bulk of steam at standard temperature and pressure would this amount of water produce? (13.)

11. How could you obtain nitrogen from (1) ammonia, (2) nitrous oxide, and (3) air? (11.)

12. In what respects does the air in a crowded room differ from fresh air? (8.)

Alternative First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

21. Describe an experiment to show that air has weight. (8.)

22. How would you prove by experiment that air, water, and iron expand on being heated? (9.)
23. Why is the gas obtained by the action of hydrochloric acid upon the black oxide of manganese termed "Chlorine"? Give some account of the properties of this gas, and name any substances known to you that contain it. (13.)
24. A piece of charcoal is heated in the air until it disappears, leaving only a white residue (ash). Give an explanation of this change. (10.)
25. What is the effect of boiling a solution of sal-ammoniac with lime or potash? Name the gas evolved, and state from what other sources it can be obtained. (13.)
26. Group the following bodies as elements or compounds, and divide the elements into metals and non-metals: lead, brass, brimstone, starch, graphite, mercury, glycerine, clay, alum, tin, calcium. (13.)
27. Name the common ores of iron, and state how cast iron is obtained from them. (15.)
28. What chemical elements are found in chalk, common salt, washing soda, blue vitriol, brass, sugar, sugar of lead, and soap? (9.)
29. How is cane-sugar obtained, and in what respects does it differ from grape-sugar? (11.)
30. What is gluten, and how is it obtained? (10.)
31. How may acetic acid be prepared (1) from alcohol, and (2) from wood? In what respects does acetic acid resemble and differ from sulphuric acid. (13.)
32. What is the chemical nature of tallow, butter, soap, oil? (12.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *eight* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

$H = 1. \quad O = 16. \quad S = 32. \quad N = 14. \quad K = 39.$

41. Explain the distinctions between an empirical formula, a rational formula, and a constitutional formula. (10.)

42. Of what use is a knowledge of the specific heat of an element to the chemist? (11.)

43. How can potassium chloride, hypochlorite, and chlorate be obtained by the action of chlorine upon caustic potash. Give the composition and properties of these salts. (12.)

44. State what experiments you would make to prove that when two substances A and B separately combine with a third substance C, the proportions of A and B which unite with C, are measures or multiples of the proportions in which A and B combine together. (15.)

45. Group the following elements according to their valency (atomicity):—bismuth, copper, tin, lead, sodium, arsenic, mercury, iron, potassium, calcium, silicon, silver.

    Explain the meaning of the terms atomic and molecular weight. (11.)

46. How is iodine prepared, and how may it be converted into hydriodic, iodic, and periodic acids? (12.)

47. 300 c.c. of a solution of caustic potash containing 40 grams KHO per litre is required to neutralise 100 c.c. of sulphuric acid, and the same volume of nitric acid. Calculate the amount of acid in each solution. (15.)

48. How are lead, mercury, arsenic, zinc, and antimony obtained from their respective sulphides? (12.)

49. Give the chemical formulæ of the following substances: galena, rock salt, dolomite, fluorspar, heavy spar, borax, calomel. (11.)

50. Give some account of the more important compounds of silicon. (12.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions.

Whenever possible, you are to express the reactions in equations.

You are to give such numerical details as will show the mode of calculation.

61. Give some account of the experiments by which Moissan has succeeded in isolating fluorine. (13.)

62. Describe the general phenomena of gaseous dissociation with special reference to the cases of nitric peroxide, phosphorus pentachloride, and ammonium chloride. (16.)

63. Write a short essay on the chemical relationships between carbon and silicon. (18.)

64. Give some account of recent work on the theory of explosion. (14.)

65. Explain in detail the experimental evidence on which the atomic theory is based. (17.)

66. How would you determine the copper, iron, and sulphur in a sample of copper pyrites? (15.)

67. Explain how it is possible to determine the molecular weight of a substance by its influence in lowering the melting point of a solvent. (16.)

68. Give an account of some of the services which spectrum analysis has rendered to chemistry. (18.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

Elementary Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

1. Give the equations which explain the changes which occur when ammonia is added to lead nitrate; nitric acid to calcium carbonate; caustic potash to ferric chloride; disodium hydrogen phosphate to magnesium sulphate; and ammonium sulphide to hydrochloric acid. (15.)

2. By what tests would you establish that the nitric acid you use as a reagent was free from hydrochloric and sulphuric acids. (10.)

3. Describe a series of experiments by which you could demonstrate the chief properties of carbon dioxide. (10.)

SUBJECT X*p*. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the elementary stage examination is confined to the qualitative analysis of two mixtures, each containing not more than two metals and one acid from the following list:

Lead, mercury, iron, calcium, magnesium, potassium, ammonium, carbonic acid, nitric acid, sulphuric acid, hydrochloric acid.

Two and a quarter hours are allowed for this part of the examination.

SUBJECT Xp. PRACTICAL INORGANIC CHEMISTRY.

Advanced Stage.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are only permitted to attempt two questions.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

Whenever possible you are to express reactions in equations.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

1. A solution contains lead and mercury and no other metal. By what tests would you fully identify these metals? Give the equation for each reaction used and apply no reaction which is not necessary. (10.)

2. How could you ascertain the presence of sulphur, phosphorus, carbon, and silicon in cast-iron? (15.)

3. Describe fully how you would prepare phosphoretted hydrogen. (10.)

SUBJECT Xp. PRACTICAL INORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Advanced Stage.

The two test substances supplied for qualitative analysis to candidates in the advanced stage consist of mixtures, each of which may consist of not more than two simple salts, the materials of which may be selected from the following list:—Potassium, sodium, ammonium, magnesium, calcium, strontium, barium, aluminium, chromium, zinc, manganese, iron, cobalt, nickel, arsenic, antimony, tin, cadmium, copper, bismuth, mercury, lead, silver, hydrosulphuric acid, hydrochloric acid, hydrobromic acid, hydriodic acid, sulphurous acid, nitric acid, chloric acid, carbonic acid, hydrofluoric acid, phosphoric acid, sulphuric acid.

Three and a quarter hours are allowed for this part of the examination.

Honours.

Three substances are supplied to each candidate in honours, two for qualitative and the third for quantitative analysis.

The two substances supplied for qualitative analysis consist of mixtures, which must be examined for all the bodies named above in the instructions for the advanced stage.

The substance for quantitative analysis need not be analysed qualitatively.

Quantitative Analysis.

Each candidate is furnished with a numbered bottle containing a powder in which carbonic acid has to be quantitatively determined.

The results must be expressed in grams of CO_2 in 100 grams of the powder.

The candidate is recommended to weigh out, *accurately*, from 0·5 to 2 grams of the powder, according to the method employed, for the purpose of analysis.

The candidate must not omit to place upon his worked paper the number attached to the bottle containing the powder he has analysed.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XI. ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND
PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

Whenever possible, you are to express the reactions by equations.

You are to give such numerical details as will show the mode of calculation.

The value attached to each question is indicated by a number placed at the end of the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

C = 12. N = 14. H = 1. O = 16.

1. Describe the method of conducting the ultimate organic analysis of ethyl alcohol. (9.)

2. In what cases is there a similarity of reaction between cyanogen and chlorine? How can cyanogen be prepared? What is the weight of 100 c.c. at the standard temperature and pressure? (13.)

3. What are the generic properties of an alcohol? (9.)

4. Why is marsh-gas classed as a paraffin? By what reactions is it usually prepared? Under what circumstances is it found in nature? (13.)

5. Describe the preparation and properties of the chief carbonyl compounds. (10.)

6. Calculate the empirical formula of a substance which has the following percentage composition:—

Carbon	...	40·00
Hydrogen	...	6·67
Oxygen	...	53·33
		100·00

(12.)

7. How can ordinary alcohol be converted into acetaldehyde and acetaldehyde into acetic acid? Is it possible to get corresponding bodies in the methyl series; if so, how? (13.)

8. Explain fully the steps by which ethyl alcohol is transformed into ethyl ether in the ordinary process of manufacture, and point out the analogy which exists between the ethereal salts and those of potassium. (13.)

9. Give examples in which chlorine acts by substitution, and others in which it does not so act. What is meant by the terms "saturated" and "non-saturated" hydrocarbons? (10.)

10. Describe the synthetical formation of ethyl alcohol. If 10 grams of pure alcohol were completely burned, what would be the weight of each product formed? (15.)

11. What is the evidence of the tetrad nature of carbon? (8.)

12. How is chloroform prepared? What are its properties and what is the action of chlorine upon it in sunlight? (11.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *eight* questions.

21. Explain how the process of substitution in the case of marsh-gas serves to establish that the atomic weight of carbon is 12. (10.)

22. What is the anhydride of a fatty acid? How is acetic anhydride obtained, and what are its properties? (12.)

23. Describe fully the method you would adopt for the ultimate analysis of chloroform. (15.)

24. Point out the relations between ethylene, glycol, glycollic acid, and oxalic acid. (12.)

25. What is the evidence that ethylene has the structure $CH_2.CH_2$ and not $CH_3.CH$? (12.)

26. Describe how morphine can be prepared from opium. What are its chemical properties, and why is it classed as an organic alkaloid? (12.)

27. Explain how you could make acetone from methyl alcohol. What are the characteristic properties of the ketones? (10.)

28. Trace the steps by which starch can be converted into alcohol. (12.)

29. How is glycerine obtained from fat? What is the experimental evidence that it is a trihydric alcohol? (10.)

30. How are malic, succinic, and tartaric acids obtained? (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt *six* questions.

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41. Explain why it is assumed that the molecule of naphthalene is formed by the combination of two benzene residues in such manner that these have two carbon atoms in common. (14.)

42. What is the general mode of action of nitrous acid upon amido compounds? How are the diazo-compounds prepared? Explain the action of water, alcohol, and hydrochloric acid upon diazo-benzene nitrate, and point out the use of these reactions in the study of the substitution products of the benzene series. (18.)

43. How is salicylic acid prepared on a manufacturing scale? Point out its relations to para- and meta-oxybenzoic acids. (16.)

44. Give some account of thiophene and its chief derivatives. (16.)

45. What are the azines (quinoxalines)? How are they prepared, and what colouring matters belong to this class? (18.)

46. Give the constitutional formulæ of the theoretically possible mono- and di-chloronaphthalenes. Describe a synthesis of α–naphthol which proves the constitution of this compound. (17.)

47. Give some account of recent work on the terpene series. (15.)

48. Describe any recent synthesis of vegetable compounds. (13.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You must take the same stage in this written examination that you are taking in the examination in Practical Analysis in this subject.

Put the number of the question before your answer.

The value attached to each question is indicated by a number placed at the end of the question.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this paper lasts for one hour.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *two* questions.

1. Describe how you would obtain anhydrous alcohol from sugar. (10.)
2. You are required to prepare some pure acetic acid from vinegar. Describe your method, and state how you would assure yourself of the purity of your product. (15.)
3. Specimens of alcohol, chloroform, and acetic acid are contaminated with water. How would you obtain them in the anhydrous state? (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *two* questions.

21. Give a sketch of the apparatus you would use, and state the precautions you would take in preparing pure ethylene. (10.)

22. Describe the methods of detecting the presence of nitrogen and chlorine in organic compounds. (10.)

23. Describe how you would prepare a small quantity of urea from potassium ferrocyanide. (15.)

SUBJECT XI*p*. PRACTICAL ORGANIC CHEMISTRY.

PRACTICAL EXAMINATION IN CHEMICAL ANALYSIS.

EXAMINERS, W. J. RUSSELL, ESQ., PH.D., F.R.S., AND PROFESSOR T. E. THORPE, B.SC., PH.D., F.R.S.

Instructions to Candidates.

Analysis Tables and Works on Chemistry may NOT be used.

Elementary Stage.

The practical work for the Elementary **Stage Examination** is confined to the qualitative analysis of two mixtures, which may each contain not more than two of the following constituents, together with an inorganic base or bases which need not be determined:—

Formic acid, acetic acid, oxalic acid, tartaric acid, salicylic acid.

Two and a quarter hours are allowed for this part of the examination.

Advanced Stage.

The practical work for the advanced stage examination is confined to the qualitative analysis of two substances, each of which may contain not more than two organic bodies selected from the following list: Hydrocyanic acid, oxalic acid, acetic acid, tartaric acid, citric acid, salicylic acid, grape sugar, starch, morphine, and urea.

Any inorganic bodies present need not be determined.

Three and a quarter hours are allowed for this part of the examination.

Honours.

The examination in Honours consists of a qualitative analysis of the two mixtures supplied, and of the determination of the percentage of chlorine contained in the organic substance distributed for this purpose.

The bottle marked (A) contains a substance in which the percentage of chlorine is to be determined by Organic Analysis.

Eight hours are allowed for the examinations in qualitative and quantitative analysis in Honours.

SUBJECT XII. GEOLOGY.

EXAMINER, H. W. BRISTOW, F.R.S., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

Instructions.

Read the General Instructions on Page 1.

You are permitted to attempt *eight* questions only.

1. How has sediment, originally soft, become converted into hard rock? (15.)
2. Describe briefly any one British stratified formation, and mention its chief fossil contents. (15.)
3. Arrange the following formations in chronological order, beginning with the newest:—Arenig rocks, Cornbrash, Gault, Wenlock Beds, Kellaways Rock, Old Red Sandstone, Chalk. (15.)
4. State the geological range in Britain of Belemnites, Rhynchonella, Ostrea, Trigonia, Nautilus, Pleurotomaria; and mention whether any of these genera are still living. (15)
5. What is Gravel? Mention some important deposit of this material, stating its composition and mode of occurrence. (10.)
6. Under what conditions and in what state is Gold usually found? (10.)
7. Mention two living genera of animals found in Palæozoic strata, and four found in Secondary strata. (10.)
8. From what rocks do we derive supplies of Common Salt, and in what ways is it obtained? (10.)

9. How are landslips caused? Mention two remarkable instances of such occurrences. (10.)

10. What is the general character of Boulder Clay? Give one explanation of its origin. (10.)

11. How are supplies of drinking-water to be obtained otherwise than at the surface of the ground? Draw a section showing favourable conditions for obtaining a supply. (10.)

12. Mention the chief districts where Granite is found in the British Islands, and give one instance where the geological age of the rock can be determined. (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.
You are permitted to attempt *six* questions only.

21. Give a short account of the Carboniferous Limestone, mentioning its chief lithological characters, the more prominent genera of its fossils, its economic uses, and the kind of scenery to which it gives rise. (40.)

22. State what inferences you would draw from the presence in one bed of Cardium, Cerithium, Cyclas, Limnæa, Littorina, Ostrea, Paludina, Planorbis, Rissoa, and Scrobicularia. (40.)

23. What great changes took place in the animal life of the British Islands at the close of the Glacial period? (30.)

24. What are "coprolites?" Mention any British formations in which they occur abundantly, and state their economic value. (30.)

25. What are Septaria? In what kinds of rock are they more commonly found? Mention three formations in which they are especially abundant, and note their economic uses. (30.)

26. State briefly the lithological characters of the following rocks, and the formations to which they belong:—Bath Stone, Pennant Grit, Cotham (or Landscape) Marble, Gannister, Penrhyn Slates, Kentish Rag. (30.)

27. Explain how the contortions which are frequently seen in Drift deposits may have been produced. (30.)

28. How may Islands be produced? Mention any evidence that leads to show the great geological age of certain islands. (30.)

29. Define what is meant by Andesite, Serpentine, Diabase, Chert, Mica-trap, and Graphite. (30.)

30. State the geological formations and zoological order to which six of the following species belong:—Ostrea deltoidea, Lingulella Davisii, Cidaris florigemma, Avicula echinata, Calymene Blumenbachii, Calceola sandalina, Terebratula maxillata, Productus giganteus, Ammonites Parkinsoni, Micraster coranguinum. (30.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on Page 1.

You are permitted to attempt *all* the questions.

The value attached to each question is the same.

41. Explain the term Laccolite, giving examples and diagrams.

42. State the principal subdivisions of the Carboniferous Limestone Series in three distinct localities in the British Islands. Note the more important products of those rocks in the districts you mention.

43. Write a short account of the Bath Waters, and give some explanation of their temperature, the depth from which they probably rise, and the origin of their saline ingredients.

44. Explain the formation of Oolitic Limestones, of Oolitic Iron-ore, and of Clay-ironstone.

45. Give some account of the Permian rocks of Britain and their fossils. State the relations (stratigraphical and palæontological) of those rocks to the Carboniferous and Triassic strata.

46. Describe some structures in rock-masses that resemble *bedding*. State how you would distinguish them, and explain how they may have been produced. Give examples, mentioning the districts in which they occur.

SUBJECT XIII. MINERALOGY.

EXAMINER, F. RUTLEY, ESQ.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the papers will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *six* questions in all, of which the last question (No. 10) is obligatory.

The value attached to each question is shown in brackets after the question.

1. In what respects does Opal differ from Quartz? (14.)
2. Give Mohs' scale of hardness, and state the approximate hardnesses of the following minerals :—Copper-pyrites, Iron-pyrites, Ruby, Biotite, Iceland-spar, and Tinstone. (14.)
3. State what you know concerning Talc and Muscovite. (14.)
4. In what systems do the following minerals crystallise :— Orthoclase, Fluorspar, Barytes, and Beryl? (14.)

5. Draw a crystal of each of the minerals mentioned in the preceding question, No. 4. (14.)

6. State the chemical composition of the following minerals:—Galena, Quartz, Orthoclase, Nitre, Diamond, and Sapphire? (14.)

7. What is meant in crystallography by the expressions "holohedral" and "hemihedral?" Illustrate your answer by two drawings. (14.)

8. Name four minerals which occur as carbonates, and which respectively yield lead, zinc, copper, and iron. (14.)

9. What are the directions of cleavage in Rock-salt, Topaz, and Fluorspar? (14.)

10. Name the three specimens placed before you. State the chemical composition of each and the system in which it crystallises. Also make a blowpipe analysis of the three powdered minerals supplied to you. State your results and the means by which you have obtained them quite clearly and briefly. (30.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions in all, of which the last two (Nos. 29 and 30) are obligatory.

The value attached to each question is shown in brackets after the question.

21. What is implied by the term "form" in crystallography? (14.)

22. Define the relative positions of the planes and axes of symmetry in a cube and in a tetragonal prism respectively. (14)

23. Describe the minerals Wulfenite, Witherite, and Pyromorphite. (14.)

24. Upon what account respectively are the following minerals of industrial importance:—Calamine, Ulexite, Cuprite, Barytes, Stephanite, and Smaltine? (14.)

25. Give a short account of the minerals classed as varieties of Hematite. (14.)

26. State what you know concerning the minerals which constitute the Pyroxene group. (14.)

27. By what characters would you distinguish an optically uniaxial from an optically biaxial crystal? (14.)

28. Draw a twinned crystal of Staurolite, marking the faces either with Naumann's or Miller's symbols. (14.)

29. Describe the six models placed before you, naming a mineral which crystallises in each of these forms. (14.)

30. Name the three specimens set before you, and state the chemical composition and crystallographic system of each. Also make a qualitative blowpipe analysis of the three powdered minerals supplied to you, clearly and briefly describing your results, and how you obtained them. (30.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions in all, of which the last (No. 48) is obligatory.

The value attached to each question is shown in brackets after the question.

41. Name any minerals isomorphous with Tinstone, stating the chemical composition of each. (14.)

42. In what respects does Hornblende differ from Arfvedsonite, Anthophyllite, and Glaucophane? (14.)

43. Describe the optical characters presented respectively by Orthoclase and Microcline? (14.)

44. Give a short description of the Manganese oxides, including Polianite. (14.)

45. State what you know concerning Leucoxene, Cymatolite, and Sagenite. (14.)

46. Describe the methods which may be employed for the determination of the directions of maximum extinction of light in crystals. (14.)

47. Describe the principal ores of Zinc. (14.)

48. Name the six specimens placed before you, stating the chemical composition of each and the system in which it crystallises. Also make a complete qualitative analysis of the three powdered minerals supplied to you, stating the results and the means by which you arrived at them. (30.)

SUBJECT XIV. ANIMAL PHYSIOLOGY.

EXAMINERS, PROFESSOR HUXLEY, LL.D., F.R.S., AND
PROFESSOR M. FOSTER, M.D., SEC. R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question in the Elementary and Advanced papers is shown in brackets after the question, but a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

You are to confine your answers *strictly* to the questions proposed.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

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1. What is the composition of ordinary atmospheric air? State exactly how expired air differs from inspired air, and explain how these differences can be proved. Explain the bad effects of breathing over again air which has been already used for breathing. (15.)
2. State the form, position in the body, and general structure of the stomach. What are the chief changes which an ordinary meal undergoes in the stomach, and in what condition does the food, which is not absorbed by the stomach, pass through the pylorus into the duodenum? (15.)
3. What is a capillary? About how big is a capillary? How does a capillary differ from an artery and from a vein? What changes take place in the blood as it passes through a capillary in such a tissue as muscle? In what parts of the body are no capillaries to be found? (15.)

4. Describe the form and general structure of the left ventricle of the heart. Describe the valves as they may be seen when the cavity is laid open. Explain how the ventricle empties itself at each beat of the heart. (15.)

5. Give an account of the position and general structure of the liver. Where does most of the blood, supplying the liver, come from? Does that blood which thus reaches the liver while digestion is going on, differ from the blood which reaches the liver when no food has been taken for some time? If so, how? (10.)

6. Explain how it is that the body has always nearly the same temperature, whatever be the temperature of the surrounding air. (10.)

7. What is "serum" of blood? What are the most important bodies present in it? How does serum differ from plasma? (10.)

8. What is the pupil? By what means does it grow larger, and by what means does it grow smaller? Why does it generally become small in the light, and large in the dark? (10.)

9. What is meant by proteid food? Give examples. Why cannot we live without proteid food? Why is it desirable to have other food besides proteids? (10.)

10. What is the form, general structure and position of the spleen? Where does the blood coming from the spleen go to? (10.)

11. Describe the structure of a muscle as far as can be made out without a microscope. What is meant by the contraction of a muscle? What change of form takes place in a muscle when it contracts? (10.)

12. What are the lacteals? How does the chyle which they contain after a meal get into the blood? (10.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

21. Describe the general form, relations and structure of the small intestine, dwelling chiefly on the minute structure of the mucous membrane. State briefly the changes which an ordinary meal undergoes in passing from the

pylorus to the ileo-cæcal valve, and explain how these changes are brought about. (26.)

22. Describe the right ventricle of the heart, including an account of the auriculo-ventricular valves, and of the nature of the ventricular walls. Give an account of the series of changes which take place in the ventricular walls and ventricular cavity during a beat, explaining the manner in which the ventricle is emptied and filled, and the causes which lead to its being emptied and filled. (26.)

23. Describe the structure of the kidney. State the changes or events in the body which cause an increase, and those which cause a decrease in the flow of urine, and explain how they act. (16.)

24. Describe briefly the structure of a pulmonary alveolus. State the changes which, in life, are taking place in the air of the alveolus, and in the blood which is circulating in the blood-vessels of the alveolus; and explain how these changes are brought about. (16.)

25. Describe the structure of a nerve, such as the sciatic, stating first what can be made out without the use of a microscope, and secondly, what can be learnt by using the microscope. What do you understand to be the nature of a "nervous impulse"? (16.)

26. What regions of the body are supplied with ciliated epithelium? Describe the structure of ciliated epithelium, and give an account of ciliary action. (16.)

27. Give an account of the structure of the olfactory organ. Distinguish between smell, properly so called, and the effect of pungent vapours such as that of ammonia. Explain how smell enters into many sensations often spoken of as "tastes."

28. Describe the general arrangement and structure of the lymphatic vessels of a limb. What is the nature of lymph, how does it differ from blood, and what are its uses? What are the chief causes which drive the lymph along the lymphatic vessels? (16.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to *attempt* only *four* questions.

The value attached to each question is the same.

41. Give an account of the inhibitory and augmentor nerves of the heart, and discuss generally the nature of the changes in a tissue by which inhibitory and augmenting effects are respectively brought about.

42. Give an account of lymph, discussing the nature of the process of transudation, the purpose served by lymph, and the causes which maintain the flow of lymph, introducing such pathological details as may be necessary.

43. Describe the differences of structure presented by the spinal cord in different regions, both as regards the distribution of nerve cells and grey matter, and as regards the "tracts" of white matter. Discuss the functional meaning of these differences.

44. Give an account of the coagulation of the blood, with reference to the exact nature of the process, and to the question why blood clots when shed.

45. State the limitations to which the movements of the eyeballs are subject, and explain how those limitations are connected with binocular vision.

46. Give an account of the chief facts of the physiology of the (mammalian) embryo during the later stages of intra-uterine life. Explain in detail the chief physiological changes taking place in the embryo at birth.

Honours Practical Examination.

1. Make preparations from the Frog to show the structure of
(*a*) *Medullated Nerve*, and
(*b*) *Spinal Ganglion*.
Label your preparations *A*, and state the methods used.

2. Stain and mount in Canada Balsam sections of either *B*. 1 or *B*. 2. Give your manipulations.

3. Draw carefully under low and high power *two* of the preparations labelled C_1, C_2, C_3.
Mark on your drawings the different structures shown.

4. What important physiological substances are present in the fluid D? Demonstrate your tests to the examiner.

5. Demonstrate the action of the vagus nerve on the Heart of a Frog.

SUBJECT XV. BOTANY.

EXAMINERS, PROFESSOR S. H. VINES, M.A., D.Sc. F.R.S.,
AND D. H. SCOTT, ESQ., M.A., Ph.D.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, in accordance with the application which has been made, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

The value attached to each question in the Elementary and Advanced stages is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *six* questions.

You must attempt the first question on the paper. The remaining five you may select from any part of the paper.

1. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem,	Flower,	Pistil,	
Leaves,	Calyx,	Fruit,	
Inflorescence,	Corolla,	Seed.	
Bracts,	Stamens,		(25.)

2. What part of its food does a green plant obtain from the air? In what form, and under what conditions, is it taken in? (15.)

3. What are stipules? Describe the stipules of the Rose and of the Sweet Pea. (15.)

4. Explain why it is that plants droop on a hot day, and recover their freshness in the evening. (15.)

5. Explain the way in which insects are of use to flowers, and the means by which flowers attract them. (15.)

6. Describe the way in which the stem of a dicotyledonous tree grows in thickness, and explain how it is that its wood shows annual rings. (15.)

7. From what parts of the flower may the fruit be developed? Describe an achene, a follicle, and a nut, giving examples. (15.)

8. Explain why it is that, when a seed germinates, the stem grows upwards and the root downwards. (15.)

9. What is meant by a "vessel"? What are the differences between the vessels of the wood and those of the bast? (15.)

10. What is a "growing-point"? What is the difference between the growing-points of stems and those of roots? (15.)

11. Give examples of different kinds of climbing plants, briefly describing the mode of climbing in each case. (15.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *six* questions.

You must attempt the *first* question on the paper, the remaining *five* you may select from any part of the paper.

21. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully, taking its organs (when present) in the following order:—

Stem, Flowers, Pistil,
Leaves, Calyx, Fruit,
Inflorescence, Corolla, Seed.
Bracts, Stamens, (25.)

22. Give an account of the structure and development of the sexual generation (oophyte) of a Fern. Describe in detail the structure of the sexual organs, and the process of fertilisation. (15.)

23. A plant, the leaves of which contain starch, is placed for some time in darkness. State and explain what effect this will have on the presence of starch in the leaves. (15.)

24. Describe fully the structure of the flower of any British Orchid, and the way in which pollination takes place in it. (15.)

25. Give an account of the structure and arrangement of the medullary rays in the stem of a Dicotyledon. What is the difference between primary and secondary medullary rays? What are the uses of the medullary rays? (15.)

26. What is meant by "phyllotaxis"? Describe the phyllotaxis in the Dead-Nettle (*Lamium*), the Bedstraw (*Galium*), and the Elm (*Ulmus*). (15.)

27. Describe the form in which nitrogenous reserve-substances are stored up in seeds. What is the general chemical nature of these substances? (15.)

28. Describe the structure, development, and function of lenticels. (15.)

29. Explain the morphology of the epicalyx (caliculus), and mention British plants in which it is present. (15.)

30. Describe the structure of a staminal cone of the Scotch Fir (*Pinus sylvestris*). Compare its structure with that of a typical angiospermous flower. (15.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

You must attempt the *first* question on the paper, the remaining *four* you may select from any part of the paper.

The value attached to each question is the same.

41. Refer the plant placed before you to its natural order, giving your reasons for doing so, and describe it fully,

taking its organs (when present) in the following order:—

Stem,	Flower,	Pistil,
Leaves,	Calyx,	Fruit,
Inflorescence,	Corolla,	Seed.
Bracts,	Stamens,	

42. Describe the minute structure of floral nectaries, and specify the various positions which they may occupy in the flower. In what respect does the mechanism of secretion in nectaries differ from that in chalk-glands?

43. Give a general account of the nyctitropic and paraheliotropic movements of leaves, and explain what is the importance of these movements to the plant.

44. Give an account of the phenomena of polyembryony as they have been observed in the Gymnosperms.

45. Mention and describe cases of the occurrence of a many-layered epidermis in leaves and roots, stating in each case what purpose is served by this peculiar development.

46. Discuss the phylogenetic relation of the Muscineæ to the Green Algæ (Chlorophyceæ).

47. Give an account of the chief anatomical peculiarities which have been observed in the stems of climbing plants.

48. State what are the isothermal lines bounding (1) the warmer temperate zone; (2) the cooler temperate zone; and (3) the subarctic zone. Mention the kinds of trees which are characteristic of these zones respectively.

Honours Practical Examination.

(Botany and Vegetable Morphology and Physiology).

MORNING, 10—1.

1. Make preparations to show at least two stages in the development of the *ovule and embryo-sac*, in the flower provided.

   Describe and draw your preparation, and refer the specimen to its natural order.

2. Make a preparation to demonstrate the presence of *starch in the chlorophyll-granules* in the leaf provided. State the methods employed.

Not more than 6 preparations in all may be shown.

They must be labelled with the name of the candidate, and be numbered for reference.

AFTERNOON, 2—4.

1. Identify and describe the four museum specimens labelled A to D.
2. Identify and *shortly* describe the four microscopical preparations labelled 1–4.

The slides must *not* be shifted.

Ten minutes are allowed for each candidate to examine each slide.

SUBJECTS XVI. and XVII. GENERAL BIOLOGY.

EXAMINER, PROFESSOR MILNES MARSHALL, M.D., F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You are permitted to answer questions from the Elementary paper;

Or from the Advanced paper in Animal Morphology and Physiology;

Or from the Advanced paper in Vegetable Morphology and Physiology;

Or from the Honours paper in Animal Morphology and Physiology;

Or from the Honours paper in Vegetable Morphology and Physiology;

But you must confine yourself to one of them.

Where the values differ, that attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will, in all cases, secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in these subjects lasts for three hours.

First Stage or Elementary Examination.

You are permitted to attempt only *eight* questions.
Illustrate your answers by diagrammatic figures.

1. State the principal points, both in structure and life-history, in which Amœba differs—(*a*) from plants, (*b*) from the higher animals? (16)

2. What are the chief purposes of the blood system? Explain where and how these purposes are effected in a crayfish and in a frog respectively. (16.)

3. Enumerate the principal forms of cell-tissues met with in the fern; and state the leading characters and properties of each. (16.)

4. What are cilia? Where do cilia occur, if at all, in the following animals:—Frog, mussel, crayfish, Hydra (fresh water polype), and Vorticella (bell animalcule)? State their use in each case. (16.)

5. Describe the process of reproduction, both sexual and non-sexual, in Chara. (9.)

6. Compare the modes in which food is captured and digestion effected in a Hydra (fresh-water polype), a crayfish, and a frog, respectively. (9.)

7. Where and in what form does chlorophyll occur in plants, and of what use is it? What plants have no chlorophyll, and how are they able to do without it? Is chlorophyll ever found in animals? (9.)

8. Give an account of the principal changes that occur during the metamorphosis of the tadpole to the frog. (9.)

9. What is a flower? Of what parts does it consist, and what are the structure and uses of the several parts. (9.)

10. Describe the structure of cartilage, and of bone. In what parts of a frog does cartilage occur? How does bone grow? (9.)

11. Describe briefly the processes that go on in the stem, in the leaves, and in the root of a flowering plant under natural conditions. How are these processes affected if the plant be grown and kept in the dark? (9.)

12. The body of a crayfish is divisible into segments. What systems show this segmental arrangement? In what other animals that you know of does a segmental arrangement of organs occur? (9.)

SUBJECT XVI. ANIMAL MORPHOLOGY AND PHYSIOLOGY.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

The value attached to each question is the same.

Illustrate your answers by diagrammatic figures.

21. What are the essential components of the vertebrate skull? Compare with one another, with special reference to the condition of the hyoid and mandibular arches, the skulls of a Cod, a Frog, a Pigeon, and a Sheep.

22. State the leading points in which the Monotremata and Marsupialia differ from each other and from other mammals.

23. Describe the formation of the germinal layers, and the development of the alimentary canal and the heart in a chick embryo. Compare the mode of nutrition of the chick embryo with that of the mammalian embryo.

24. Marsupials are confined at the present day to the Australian and Neotropical regions. What evidence have we as to the way in which this distribution came about? Give other instances of discontinuous distribution, and explain them as far as you are able?

25. Describe the arrangement and structure of the excretory (renal) organs in a leech, a liver fluke, and an earthworm. Which of these do you consider to be the most primitive; and why?

26. Give a general account of the structure of a Cuttlefish or of an Octopus. How do its circulatory, respiratory, renal, and nervous systems differ from those of a Snail?

27. Describe the structure and mode of formation of a jelly-fish; and compare it with a Hydra and with a Sea-anemone. Give examples of hydroid colonies, and explain how they are formed.

28. Tabulate the several modes of reproduction met with among the Protozoa; and state which of these occur among the higher animals.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

The value attached to each question is the same.

Illustrate your answers by diagrammatic figures.

41. What grounds are there for believing the pulmonate vertebrates to be descended from branchiate vertebrates; and what evidence have we as to the actual line of descent? Give examples of invertebrate groups in which air-breathing forms are derived from water-breathing ones.
42. Give an account of the various modes in which the nutrition of the embryo is effected in animals. Explain fully the influence of food-yolk on the development of the embryo.
43. Discuss fully the relations of the Crinoidea to the other recent Echinodermata.
44. Give an account of the anatomy and development of *either* Peripatus *or* Balanoglossus; and discuss fully the zoological position and affinities of the form you select.
45. What are the chief modifications presented by the skeletal structures of Cœlenterata?
46. Describe the leading forms of eye met with among Arthropoda. What evidence have we as to the mode of origin of compound eyes?

Honours Practical Examination.

10 A.M.—1 P.M.

1. Dissect A so as to show the nervous and reproductive systems as fully as you can. Name the several parts of their systems by small paper labels.
2. Put up microscopical preparations, illustrating the anatomy and the modes of reproduction of B. Draw your preparations, and describe them briefly.
3. Identify, draw, and describe briefly the specimens C, D, E, F, G, H.

A. Aplysia.
B. Pyrosoma.
C. Section of calcareous sponge.
D. Section Pontobdello.
E. Sections of Balanoglossus.
F. Section of young Sepia, showing eye.
G. Section of a Hemertine.
H. Leptodora Hyalina.

2 to 5 P.M.

1. Refer to their proper zoological positions the animals K, L, M, N. Make dissections or other preparations illustrating the points on which you rely in your determinations. Describe your preparations briefly.

2. Describe briefly the characteristic features of the skulls O, P, Q; including the dentition.

3. Identify and draw the specimens R, S, T, U. Name on your drawings the several parts shown.

K. Petromyzon.
L. Arenicola.
M. Musca.
N. Apus.
O. Hypsiprymnus.
P. Pteropus.
Q. Erinaceus.
R. Chick embryo: section.
S. Amphioxus.
T. Chick embryo: section.
U. Peripatus.

SUBJECT XVII. VEGETABLE MORPHOLOGY AND PHYSIOLOGY.

EXAMINERS, PROFESSOR VINES, M.A., D.Sc., F.R.S., AND D. H. SCOTT, Esq., M.A., Ph.D.

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *five* questions.

The value attached to each question is the same.

51. Describe the structure and development of the sporangia and spores in any Fern.

52. Describe the structure and mode of development of root-hairs, explaining the nature of their functions.

53. State what are the characteristic features of Gymnosperms which may be observed in the carpellary flower (female cone), and in the ovule, of *Pinus*.

54. Describe and compare the general structure of the gynæceum (pistil) in the flowers of *Ranunculus*, *Rosa*, and *Anthriscus*.

55. Describe the histology, and the modes of secretion, of the various internal secretory structures of plants.

56. Give an account of the general structure, of the modes of reproduction, and of the habit of life of *Peronospora*.

57. Mention cases illustrative of the various ways in which plants absorb organic compounds as food, explaining fully how the food is obtained in each case.

58. Give a comparative account of the life-histories of *Volvox* and of *Protococcus*.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *four* questions.

The value attached to each question is the same.

61. Describe the various modes of the sexual process in the brown Algæ (Phæophyceæ), and trace the gradual morphological differentiation of the sexual organs and of the sexual cells (gametes) in the various families of this group.

62. Describe the typical mode of development of the embryo in Monocotyledons, and discuss the value of embryological characters as distinguishing Monocotyledons from Dicotyledons.

63. Discuss the question of the mode in which green plants obtain their nitrogenous food, and of the sources from which it is derived.

64. Give an account of the comparative morphology of the oophyte (sexual generation) in the Muscineæ, the Vascular Cryptogams, and the Gymnosperms.

65. State what is known as to the structure and functions of the nucleus (*no minute description of nuclear division is required*). In what cases have multinucleate cells been observed in plants?

66. Describe the development of the archicarp (ascogonium) and of the perithecium in *Eurotium*. Discuss the question of the homology of these structures with the procarpium and the cystocarp of the Florideæ.

(N.B.—The questions set at the Honours Practical Examination will be found at pp. 109–110.)

SUBJECT XVIII. PRINCIPLES OF MINING.

EXAMINER, H. BAUERMAN, ESQ., F.G.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *seven* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

1. What are minerals, as the term is understood by miners?
2. Describe the general structure of a coal-field.
3. With what rocks and minerals is coal usually associated?
4. Give the shape and dimensions of a borer or drill suitable for boring in hard rock, and describe the method of sharpening and tempering the bit.
5. Describe and illustrate the use of timber in securing a round or rectangular mine shaft.
6. How is ventilation effected in a mine on a lode?
7. What gases are usually found in the air of a coal-mine?
8. What is a safety load for a steel pit rope, and how should such a rope be protected in use?
9. Give a description and figure of the bottom lift of a deep mine pump.
10. Describe the Barnsley method of working coal.

11. How is tin ore found and prepared for the smelter?
12. What methods are used in cleaning small coal from shale and brasses?

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *seven* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

21. Describe the physical characters and composition of steam coal, coking coal, cannel, and oil-shale.
22. What are the chief kinds of deposits of lead ore in the United Kingdom? Give examples from the principal localities.
23. How would you put down a deep boring for coal or salt?
24. What are the principal nitro compounds useful as mining explosives?
25. Describe with figures two kinds of safety catches for deep mines.
26. What methods are used for equalizing the load on winding engines?
27. Describe Poetsch's method of shaft sinking.
28. Give an account of a method of working a thick coal with a bad roof.
29. Describe two of the best forms of safety lamps.
30. Describe the more important localities producing manganese ore.
31. Give an account of an underground pumping engine.
32. Describe the Brunton frame and Frue vanner.

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are only permitted to attempt *six* questions.

You may select these from any part of the paper.

The value attached to each question is the same.

41. Describe the South Wales coal-field, and notice the other basins on the same axis.

42. Describe the more important centres of production in the iron ore districts of the Secondary formations in England and on the continent of Europe.

43. How are wrought iron and steel used instead of timber in shafts and levels? Give some examples and illustrations.

44. Describe a method of working a thick and highly inclined coal seam in which the excavated ground is filled with waste from the surface.

45. Give an account with details of construction of a modern pit-frame in iron or steel.

46. Compare Guibal's and Waddle's ventilating fans.

47. What methods have been proposed to prevent flame in the use of explosives in collieries?

48. How have magnets been applied in the separation of zinc blende from spathic iron ore?

SUBJECT XIX. METALLURGY.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question and of the section before your answer.

You are to confine your answers *strictly* to the questions proposed; answers extending beyond the scope of the questions are disregarded by the Examiner.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not to attempt more than *six* questions in this paper.

The value attached to each question is the same.

For a pass in the Elementary stage the student will only be expected to answer questions in *two* of the following *four* sections. At least two questions must, however, be taken from Section I.

For a FIRST CLASS in the Elementary stage the candidate must answer questions in at least *three* sections. At least two questions must be taken from Section I.

SECTION I.

1. What is a "regulus," a "slag," a "speise," and a "flux"? Give an example of each.
2. Describe fully the difference between a reverberatory furnace and a blast furnace, and give an example of the kind of operation you would conduct in each.
3. What is meant by the statement that the calorific power of charcoal is 8,080 units, and that of carbonic oxide 2,403 units?
4. What is the difference in composition between bituminous coal and anthracite?

SECTION II.

5. You are given two samples of ore which closely resemble each other; one is hæmatite (Fe_2O_3), and the other is cinnabar (HgS). How would you ascertain which is the iron ore?
6. Why does cast, or "pig," iron melt readily, while wrought iron is so infusible?
7. Describe fully the conversion of pig iron into malleable iron by the puddling process.
8. What is "crucible cast-steel"? How is it manufactured?

SECTION III.

9. How would you separate silver from the amalgam of silver and mercury?
10. You are given an alloy containing 3 parts of silver and 1 part of gold. How would you "part" or separate the metals?

11. Describe generally the method of treating gold quartz with a view to separate the gold.

12. How, on a large scale, may gold be extracted from the solution of its chloride?

Section IV.

13. State what method you would employ in order to produce (*a*) "grain tin," and (*b*) *either* granulated lead or granulated copper.

14. How would you extract metallic lead from a sample of "red lead"?

15. What are the reactions which take place when partially roasted copper ores are smelted for "coarse metal"?

16. How would you extract zinc from its sulphide?

Second Stage or Advanced Examination.

Instructions.

Read the General Instructions at the head of the Elementary paper.

You are not to attempt more than *six* questions in this paper.

The value attached to each question is the same, except No. 24, of which the value is twice the value of each of the other questions.

For a pass in this stage the student will only be expected to answer questions in *two* of the following *four* sections; at least *two* questions must, however, be taken from Section I.

For a First Class in this stage the candidate must answer questions in at least *three* sections; at least *two* questions must be taken from Section I.

Section I.

21. How would you employ (*a*) peat, and (*b*) small coal to the greatest advantage, as a source of heat?

22. Show, by the aid of a sketch, any form of coke oven in which coking is effected under pressure.

23. What is the principle upon which the Siemen's regenerative furnace depends? Illustrate your answer by a sketch?

24. Name the six specimens submitted to you.

SECTION II.

25. How do you account for the fact that steel can be hardened by rapid cooling from a high temperature, while pure, or wrought, iron cannot?

26. What are the physical and mechanical properties of an alloy which contains 7 per cent. of manganese and 0·5 per cent. of carbon?

27. By what reactions does the phosphorus in the fuel and ore, charged into the blast furnace, pass into the pig iron?

28. Describe the method of lining a Bessemer converter with a basic material, and illustrate your answer by a sketch.

SECTION III.

29. Describe the reactions which take place when an auriferous and argentiferous sulphide containing iron and copper, is roasted with common salt.

30. Zinc blende is frequently rich in silver; how would you separate this metal?

31. You are required to separate the silver present in a solution of cupric chloride. What precipitant, other than metallic copper, would you employ?

32. How would you prepare a small quantity of very pure gold?

SECTION IV.

33. What are the principal reactions involved in the separation of the following metals from their ores:—(*a*) Tin, (*b*) Copper, (*c*) Zinc, and (*d*) Lead.

34. Draw a comparison between the "roasting" and the "refining" stages of the Welsh method of copper smelting.

35. Describe a process to which a speise containing nickel and cobalt would be subjected, with a view to concentrate the speise and increase the percentage of metals.

36. In the treatment of gold ores by mercury, large quantities of mercury are lost by "flouring" or "sickening." How may this be avoided?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to attempt more than *eight* questions, and in these No. 51 must be included.

The value attached to each question is the same.

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40. **Give an outline of the evidence which supports the view that metals can assume allotropic states.**
41. Describe a method of preparing metallic lead in a state of aggregation which renders it suitable for use in secondary batteries.
42. What are the principal reactions by which silver is separated from its ores in *either* the Patio process *or* in pan amalgamation?
43. Illustrate, by means of a sketch, the general arrangement of the appliances used in the Newbery-Vautin chlorination process, and state what advantages are claimed for the process.
44. How would you separate from the worn-out zincs of an electrical battery, the mercury with which they had been amalgamated?
45. Give a brief description of the principles upon which Castner's process for producing sodium depends.
46. Describe any method which has recently been proposed for carburizing wrought iron.
47. What explanation has recently been given of the phenomenon of "recalescence" in iron?
48. Show, with the aid of a sketch, the general arrangement of the Husgafvel furnace used in the production of wrought iron "blooms."
49. Give a sketch of the furnace used in the Manhés process for "Bessemerizing" copper regulus, and state what advantages are claimed for the process.
50. How may copper be separated from gold by a method not involving the use of acids?
51. Name and describe briefly the six specimens submitted to you.

SUBJECT XIXp. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Elementary Stage.

Three hours are allowed for this examination.

1. The candidate is required to prepare hard solder from the tin and lead given to him. He is to calculate the composition of the alloy he produces from its weight.

2. The candidate is required to form sulphide of antimony from the antimony and sulphur given to him. He is to deduce the chemical composition of the product from the increase in weight of the antimony.

Note.—The candidate must place the number of his examination paper on the products he obtains, and hand them to the Superintendents of the examination, to be returned to the Department for examination.

SUBJECT XIX*p*. PRACTICAL METALLURGY.

PRACTICAL EXAMINATION.

EXAMINER, PROFESSOR W. CHANDLER ROBERTS-AUSTEN, F.R.S.

Instructions to Candidates.

Works on Metallurgy may be used.

Abundant samples are sent in each case; the amount to be actually used is left to the candidate's discretion.

Advanced Stage.

Four hours are allowed for this examination.

1. The candidate is required to prepare "German silver," containing 15 per cent. of nickel, from the three metals supplied to him. He is to calculate the composition of the alloy he produces from its weight.
2. The candidate is given a sample of copper containing silver. He is required to separate the silver from the copper, and to determine the amount of silver originally present in the copper.

Note.—The candidate must place the number of his examination paper on the product he obtains in the *first question*, and he must wrap up in paper (bearing the number of his examination paper) the silver he obtains in the second question. The products are to be handed to the Superintendents of the examination, to be returned to the Department for examination.

Honours.

Eight hours are allowed for this examination.

1. The candidate is required to determine the amounts of tin and zinc in the sample of bronze given to him.
2. The candidate is required to determine, by the cyanide of potassium method, the percentage of copper in the sample of ore given to him. The ore contains a metal which interferes with the accuracy of the result. The candidate is to describe the nature of the ore and to find by a qualitative examination what interfering metal is present.

Note.—None of the samples or products are to be returned.

SUBJECT XX. NAVIGATION.

EXAMINER, REV. J. B. HARBORD, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

In all cases the number of the question must be placed before the answer on the worked paper.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are only permitted to attempt *eight* questions, viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Define a sphere. What facts lead to the conclusion that the earth is approximately a sphere? Strictly speaking, what is the figure of the earth? Define great and small circles of a sphere. Define a degree, and mention its subdivisions. How many degrees are there in a great circle, and how many in a small circle? (12.)
2. Define latitude, longitude, difference of latitude, difference of longitude.

   A ship sails from A to B without changing her latitude, with what does her rhumb line then coincide? A ship sails from C to D without changing her longitude, with what does her rhumb line coincide in this case?

Define course and distance. Is this distance generally the shortest road from one place to another? Mention any case when it is. (12.)

3. Draw a compass card, inserting only the cardinal points and those which are 22° 30′ distant from the cardinal points.

If the variation of the compass be 33° 45′ W., indicate on your figure, by the letters N′ and S′, where the magnetic north and south would be.

How many points are there in the arc SS′; and how many degrees, &c., in the arc S′E?

Define deviation. The variation is one point E, and the compass points true north, what is the amount of the deviation?

Define leeway. Under what circumstances is the leeway greatest and when is it least? (13.)

4. State clearly the principle which enables you to obtain the distance by the use of the common log. Also state clearly the principle of Massey's and Walker's patent logs.

What do you mean by sounding? What are the objects of taking soundings? Describe the common instruments used. (13.)

5. What is the use of the Traverse Table? Describe it and show how it is constructed. (12.)

6. What do you understand by the terms plane sailing, traverse sailing, and middle latitude sailing?

Give and prove the formula for middle latitude sailing. (12.)

Section II.

7. What distance must a ship in latitude 40° 20′ S. sail on the parallel of latitude in order to change her longitude by 10° 30′? (5.)

8. A ship sails from Easter Isle (lat. 27° 10′ S., long. 109° 25′ W.), 186 miles, S.E. by S.; required the latitude and longitude in. To be worked by middle latitude method. (10.)

9. Required, by middle latitude sailing, the course and distance from Plymouth (lat. 50° 22′ N., long. 4° 7′ W.) to Cherbourg (lat. 49° 38′ N., long. 1° 37′ W.). (10.)

10. Find the latitude and longitude in, the ship having sailed from a place in lat. 49° 27′ N., and long. 37° 8′ W., 89 miles S.E. by S. by compass; variation three points W., deviation 8° 20′ E. (13.)

11. Find the compass course and distance from Quiloa (lat. 8° 41′ S., long. 39° 47′ E.) to C. Amber (lat. 12° 2′ S., long. 49° 25′ E.); variation $1\frac{1}{4}$ point W., deviation 12° W. (13.)

12. Find the latitude and longitude in, of a ship which sails as follows, from a place in lat. 20° 54′ N. and long. 78° 35′ E.:—

True courses.	Distances.
N.E.	20
S.	58
S.S.W.	120
W.	95
N.W.$\frac{1}{2}$W.	79

(14.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt all or any of the questions.

21. Compute the length of a nautical mile.

There are two log-lines on board, the knot on one measuring 50 feet and on the other 44 feet, and the log-glass runs out in 28 s. In making land which of these two lines would you prefer using, and why? Taking the nautical mile as 6,080 feet, find the error of the knot on each line. (20.)

22. Describe the construction of Mercator's Chart, and point out its special convenience for the purposes of navigation. (20.)

23. Find, by Mercator sailing, the compass course and distance (1) from Ajaccio (lat. 41° 55′ N., long. 8° 44′ E.) to Barcelona (lat. 41° 22′ N., long. 2° 9′ E.); and (2) from Barcelona to Ajaccio. Variation $1\frac{3}{4}$ points W.; deviation for ship's head on first passage $\frac{3}{4}$ point W., and on return passage $\frac{1}{4}$ point W. (25.)

24. A ship, A, leaves C. Farewell (lat. 59° 42′ N., long. 45° 16′ W.), and another ship, B, leaves C. Wrath (lat. 58° 30′ N., long. 5° 0′ W.). How far would each have to sail on the arc of the great circle between these two places, to the vertex? (30.)

25. Mention the different methods employed for making a Table of Deviations, and describe one fully. What is the meaning of the terms Semicircular and Quadrantal Deviations, and to what causes are they respectively due? (20.)

26. Two ships, A and B, leave the meridian of 34° W. together, A's latitude being 49° 30′ N., and B's latitude being 39° 23′ N.; A sails due east, and B sails N.E. by E.; and they meet in longitude 20° W. Compare their rate of sailing. (25.)

27. Give the length of the polar diameter of the earth and of the polar compresion.

Find in what latitude the arc of the parallel is $\frac{3}{5}$ths of the arc of the equator intercepted between the same meridians. (20.)

28. February 6th, 1889, at noon, Cape St. Mary, Madagascar (lat. 25° 50′ S., long. 45° 0′ E.), bore by compass N.E. (ship's head being south), distant 10 miles; afterwards sailed as by following log account; variation 2 points W. Required the latitude and longitude in, on February 7th at noon. (40.)

H.	K.	$\frac{1}{10}$ths.	Courses.	Wind.	Leeway Points.	Remarks.
1	4	2	South.	W. by S.	1	Deviation 5° E.
2	5	4				
3	6	6				
4	6	8				
5	7	0				
6	5	1	S.W. by W.	W.N.W.	2	Deviation 9° E.
7	8	3				
8	8	5				
9	7	7				
10	6	9				
11	4	2				
12	3	3				
1	5	4	S.S.E.	West	½	Deviation 3° E.
2	6	9				
3	7	8				
4	8	7				
5	6	8				
6	5	6	W. by N.	North	1	Deviation 4° 30′ W.
7	8	3				
8	9	2				
9	9	1				
10	8	0	S. by E.	N.N.E.	0	Deviation 6° E.
11	7	3				
12	6	5				

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt all or any of the questions.

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41. Draw a portion of a Napier Deviation Diagram extending from the north to the east point, and the included deviation curve; given that:

When the ship's head is N., the deviation is 4° W.
" " N.N.E. " " 8° 30′ E.
" " E. by N. " " 22° E.
" " E. " " 20° E.

Take off—

(1) The deviation when the ship's head is N.E. by N.
(2) The magnetic course corresponding to compass course E.N.E.
(3) The compass course corresponding to magnetic course E.N.E. (70.)

42. In the month of August, a ship in latitude 20° N., and longitude 65° W., has indications of the approach of a revolving storm, and she at once heaves-to. What are these indications? The wind is N.E. at the commencement of the storm; what is the bearing of the centre? The wind veers to E.N.E. and E.; on which side of the storm's path does the vessel lie? On what tack should she be hove-to? Give the reason. What would indicate that a ship lies in the direct path of the storm's centre, and what should then be done? (40.)

43. Define meridional parts. Give and prove an approximate formula for constructing a table of meridional parts. Is it quite correct to assume that degrees of latitude are the same length on every part of the earth's surface? If not, state where and why they increase in length. (40.)

44. In making a survey of a harbour, two known objects, A and B, are observed to be in the same line from the position of the observer S, the position it is desired to fix; and the angle B S P is observed, P being another object whose position is known. Show how you can fix the position of S. What is the use of the station-pointer. (40.)

45. If h be the height of the mast-head in feet, m the number of minutes in the mast-head angle, D the distance of the ship from the observer in fathoms; show that $D = \frac{573 \times h}{m}$ very nearly. (40.)

46. Two ships, A and B, leave together a place L, and steam direct for a point P, 20 miles distant, L and P being in the same latitude; A's course, by compass, is S.E. by E., and her rate 8 miles an hour; B's course, by compass, is E. by S., and her rate is 6 miles an hour. At the end of 2 hours A observes the point to bear by compass E. by S., and B observes it to bear by compass E. Find the direction and rate of the current, and show how the Traverse Table may be used in solving the problem. (40.)

47. Shew how to find the position of a succession of points on the arc of the great circle joining two places. Of what practical use is this problem?

Find the position of a series of 4 points on the great circle joining C. Clear (lat. 51° 25′ N., long. 9° 29′ W.), and C. Race (lat. 46° 40′ N., long. 53° 3′ W.); having given lat. of vertex 51° 50′ 30″ N., long. of vertex 19° 26′ 30″ W. (40.)

48. Construct a Mercator Chart on a scale of 1·8 inch to a degree of longitude, extending from 120° to 123° east longitude, and from 63° 30′ to 65° 30′ south latitude. Take out the meridional parts for every half-degree, and draw meridians and parallels at that interval.

A ship leaves a place A (lat. 65° 7′ S., long. 120° 52′ E.), and sails to B on the following true courses and distances: N.E., 47 miles; N.N.W., 63 miles; S.W. by S., 42 miles; east, 27 miles. Lay down the courses and distances, and take off the lat. in and long. in. Give also the magnetic bearing of A from B, the variation being 8° 30′ W. (90.)

SUBJECT XXI. NAUTICAL ASTRONOMY.

EXAMINER, Rev. J. B. HARBORD, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

The value attached to each question is shown in brackets after the question. But a full and correct answer to an easy question will in all cases secure a larger number of marks than an incomplete or inexact answer to a more difficult one.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

You are only permitted to attempt *eight* questions, viz., *four* out of each of the sections into which the paper is divided.

SECTION I.

1. Define vertical circles and the prime vertical. Draw a circle to represent the prime vertical, and name and indicate the points where the meridian and the horizon would cut the circle. What are the points called where the meridian and horizon intersect each other? What is the azimuth of a body when it is on the prime vertical? (12.)
2. Define the following terms, which are found in pages I. and II. of Nautical Almanac:—apparent noon, mean noon, apparent time, mean time, equation of time. There are two places A and B, A being 15° to the East of B: explain clearly why, when it is 3 o'clock at A, it is 2 o'clock at B. (12.)
3. Explain by a figure what you mean by the angular distance between two points. Explain how the sextant enables you to measure an angular distance. What are the two points whose angular distance you measure when you take the altitude of the sun's lower limb? Define index error. (12.)
4. Explain clearly how a chronometer assists you to determine the longitude at sea. What observation with the sextant do you take, and what part of the problem does this enable you to determine? Define error and rate of chronometer. (12.)
5. Define altitude of a heavenly body, and distinguish between observed, apparent, and true altitude. Define dip, refraction, parallax. Why is it necessary to use a correction for semidiameter in finding the altitude of the sun? (12.)
6. Prove the rule for finding the azimuth of the sun, having given his altitude and declination and the latitude of the place. Draw diagrams, projecting on the horizon for the following cases: (1) latitude N., declination N., sun E. of meridian; (2) latitude S., declination N., sun W. of meridian. (14.)

SECTION II.

7. January 20th, 1889, in longitude 33° W., the observed meridian altitude of the sun's lower limb was 23° 10′ 30″; zenith north of the sun, index correction + 1′ 30″, height of eye above sea 22 feet. Required the latitude. (8.)

8. June 10th, 1889, at 6^h 25^m a.m., mean time nearly, in latitude 40° 20′ N., and longitude by account 42° 30′ W., when a chronometer showed 9^h 45^m 50^s, the observed altitude of the sun's L.L. was 19° 17′ 15″; index correction − 3′ 0″, height of eye 19 feet.

   On May 30th, at noon, the chronometer was fast on G.M.T. 30^m 20^s, and its rate was $3{\cdot}8^s$ gaining. Required the longitude. (14.)

9. April 22nd, 1889, at 4^h 45^m p.m., mean time nearly, in latitude 36° 40′ 10″ N., and longitude 0, when a chronometer showed 5^h 30^m 12^s, the observed altitude of the sun's L.L. was 21° 24′ 20″; index correction + 4′ 10″, height of eye 24 feet. Required the error of chronometer on S.M.T. and on G.M.T. (12.)

10. August 5th, 1889, at 5^h 20^m a.m., mean time nearly, in latitude 30° 30′ S. and longitude 67° 40′ E., the sun rose by compass E. 10° 20′ N. The deviation of the compass for direction of ship's head being 5° 40′ E., find the variation. (12.)

11. December 15th, 1889, at 3^h 30^m p.m., Greenwich mean time, in latitude 50° 20′ N., the observed altitude of the sun's U.L. in artificial horizon was 17° 40′ 20″; index correction − 2′ 40″. Required the sun's azimuth. (12.)

12. When the sun was on the prime vertical, he was observed by azimuth compass to bear E.N.E.; the variation at the place, by chart, was 10° 30′ E. What was the deviation of the compass when the observation was taken?

    Find the correct declination of the sun on 20th March, 1889, when on the meridian of a place in longitude 34° 30′ E. (12.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt *all* or any of the questions.

21. Investigate the method of finding the latitude from the altitude of an object near the meridian, without using the estimated latitude. (25.)

22. May 6th, 1889, in latitude by account 45° 25′ N., longitude 140° 30′ W., the following observations were taken:—

App. time at ship nearly.	Chronometer.	Obs. Alt.	Mag. Bearing.
$2^h\ 12^m$ p.m.	$12^h\ 3^m\ 5^s$	49° 51′ 20″	S.W. $\frac{3}{4}$ W.
4 49 p.m.	2 39 23	24 4 30	W. $\frac{1}{2}$ N.

The run of the ship in the interval was mag. south at rate of 6 miles per hour; the chronometer was fast on G.M.T. $32^m\ 20^s$ on May 1st, and its rate $\cdot 7^s$ losing; index correction + 3′ 40″; height of the eye 20 feet. Required the true latitude at the second observation. (30.)

23. Explain why when the moon and the sun have the same true zenith distance, the moon has a lower apparent altitude than the sun.

Define apparent distance and true distance between two heavenly bodies.

What do you mean by clearing the lunar distance? Explain, by a figure, how the formulæ are obtained for this problem.

How does the lunar distance enable you to obtain Greenwich mean time? What else is necessary for determining the longitude, and how is it obtained? (25.)

24. April 25th, 1889, at $12^h\ 15^m$ p.m., mean time nearly, in latitude 47° 23′ N., and longitude by account 33° 10′ W., when chronometer showed $1^h\ 58^m\ 17^s$, the observed altitude of *Regulus* W. of the meridian, was 24° 42′ 13″; index correction + 3′ 40″, height of the eye 19 feet. On April 5th, the chronometer was $29^m\ 50{\cdot}3^s$ slow on G.M.T. and its rate ·5 gaining. Find the longitude. (25.)

25. Define rate of chronometer, and show how it may be obtained by equal altitudes of the same star on the same side of the meridian on different days.

Explain shortly what you mean by the equation of equal altitudes; and show that it must be added to or subtracted from the mid-time shown by chronometer, according as the polar distance of the sun is increasing or decreasing.

Show how to find the approximate time by chronometer, when an object will have the same altitude west, as it had east of the meridian. (25.)

26. June 10th, 1889, at $9^h\ 55^m$ a.m, mean time nearly, in latitude 50° 20′ N., and longitude 20° 10′ W. A chronometer showed $11^h\ 0^m\ 0^s$, its error being $20^m\ 24^s$ slow. Find the true bearing of the sun.

The bearing of the sun by compass was observed to be S.S.E. $\frac{3}{4}$ E.; the variation was 30° 30′ W. Find the deviation for the position of the ship's head. (25.)

27. Explain clearly what the semidiameter of the moon is, as given on page III. of Nautical Almanac; and show why it is necessary to have the table called the "Augmentation of the Moon's Horizontal Semidiameter."

Prove the formula

$$a = 2\,s\cos\frac{2\,z - p}{2}\sin\frac{p}{2}\operatorname{cosec}(z - p)$$

where a is the augmentation, s the horizontal semidiameter, p the parallax, z the apparent zenith distance. (25.)

28. July 20th, 1889, in longitude 40° 30′ W.; find which bright stars, put down in the Nautical Almanac, will pass the meridian between the hours of 10 and 12 p.m.

Find at what time α Lyræ will pass the meridian.

When on the meridian the altitude of this star was observed to be 42° 8′ 20″, bearing north; index correction – 2′ 40″; height of eye 18 feet. Required the latitude. (20.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt *all* or any of the questions.

41. August 11th, 1889, at $12^h\,40^m$ a.m., mean time nearly, in latitude 10° 30′ N., and longitude by account 26° 30′ W., the following lunar observations were taken:—

	Obs. Alt. Jupiter. W. of Meridian.	Obs. Alt. Moon's L.L.	Obs. dist. F.L.
	20° 56′ 15″	58° 48′ 5″	48° 31′ 35″
Ind. cor.	3 10 –	4 20 –	3 0 +

Height of eye 18 feet. Find S.M.T. from planet's altitude, and the longitude. (70.)

42. Investigate the formula from which the Tables, in Nautical Almanac, pp. 477–9, are calculated, used for finding the latitude by an altitude of Polaris. (40.)

43. At a certain place, in north latitude, on the same day, the hour angles of *Pollux* when on the prime vertical and when setting, were respectively $4^h\,13^m\,58^s$ and $8^h\,41^m\,54^s$. Find the latitude of the place, and the declination of the star. (50.)

44. Prove Ivory's method for obtaining the latitude from double altitudes, with Riddle's extension for determining the longitude.

When the sun is the body observed, at what periods of the year would the result be most correct, and why? (45.)

45. Given an error in the altitude, find an expression for the corresponding error in the hour angle.

When has a given error in the altitude the least effect on the hour angle?

Find the error in the hour angle corresponding to an error of 3′ in the altitude at a place in latitude 45° 30′: (1) when the body bears S. by W., (2) when it bears W. by S. (45.)

46. Why cannot the exact value, at any given date, of the quantities tabulated in the Nautical Almanac, at successive equal intervals of time, be determined by interpolating by simple proportion?

Explain what is meant by the Equation of Second Differences, and show how to find it.

In what practical problem may the neglect of this correction considerably vitiate the reckoning?

Find, by interpolation of second differences, the true declination of the sun at 6^h apparent time at Greenwich, on 21st June, 1889. (50.)

47. What is about the length of the lunar day, and what is the average interval between two successive times of high water at the same place?

Explain what is meant by the priming and lagging of the tide, and why the former takes place during the 1st and 3rd quarters of the moon, and the latter during the 2nd and 4th quarters.

Distinguish between Vulgar Establishment of the Port and Corrected Establishment of the Port.

Which of these is it that is registered on the Admiralty Charts, and what is its use?

Give a definition of the Establishment of the Port which expresses the interval in apparent time.

Define Age of the Tide and the Lunitidal Interval. (50.)

48. Define Meridian Distances. What are Secondary Meridians, and to what practical use are they applied?

Give a formula for finding the "sea rate" of a chronometer when running a meridian distance between A and B.

January 3rd, 1889, on leaving Madras, longitude 80° 14′ E., a chronometer was fast on Madras mean time $2^h\ 25^m\ 10 \cdot 5^s$; on January 6th, on arriving at Cicacole, the error on mean time at place was found to be fast $2^h\ 18^m\ 14^s$, and on January 10th, before leaving for the return voyage, the error was $2^h\ 18^m\ 32{\cdot}8^s$ fast; on arriving again at Madras on January 13th, the error on mean time at place was $2^h\ 26^m\ 0{\cdot}3^s$ fast. Find the sea rate of chronometer, the meridian distance of the two places, and the longitude of Cicacole. (50.)

SUBJECT XXII. STEAM.

EXAMINER, PROFESSOR GOODEVE, M.A.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are not permitted to attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

1. In an atmospheric pumping engine how is the injection water and condensed steam got rid of? Sketch and explain some of the principal improvements made by Watt in engines of this kind. (15.)

2. Describe, with sketches, the alterations made by Watt in order to convert a single-acting into a double-acting engine. (15.)

3. What is the latent heat of steam at 212° F. expressed in foot-pounds? If 1 lb. of steam at 212° F. is mixed with 10 lbs. of water at 60° F., find the resulting temperature. (15.)

4. Steam expands in the cylinder of an engine from a pressure of 30 lbs. above the atmosphere to 5 lbs. below the atmosphere, at what part of the stroke was the steam cut off? The pressure of the atmosphere may be taken at 15 lbs. (15.)

5. Describe, with sketches, the construction of a horizontal direct acting engine, working with high pressure steam and without condensation, showing how the steam is admitted into the cylinder and let out again as required. (20.)

6. Define the lap of a slide valve, and explain your answer by reference to a sketch. Account for the difference in the working of two engines, one of which has lap on the steam side of this valve and the other has not. (15.)

7. Sketch the end of the connecting rod of a locomotive engine which embraces the crank pin. Show clearly the method of tightening the brasses on the crank pin by a gib and cotter. (15.)

8. Marine engines are fitted with a so-called air pump, circulating pump, feed pump, and bilge pump. What are the respective uses of these pumps? Show, with a sketch, the construction of any one of them, and explain how it acts. (15.)

9. The stroke of a direct acting engine is 5 feet and the crank shaft makes 30 revolutions per minute, find the mean speed of the piston in feet per minute. State your reasons for concluding that there is no loss of work from the oblique action of the connecting rod during successive portions of the stroke. Friction is neglected. (15.)

10. Why are the longitudinal joints in cylindrical boilers usually double rivetted, while the transverse joints are only single rivetted? Sketch in longitudinal section a marine high pressure boiler. (15.)

11. Sketch and describe the following safety valves:—

    (1.) An ordinary lever valve.
    (2.) The Ramsbottom spring loaded valve.
    (3.) An ordinary dead weight valve. (20.)

12. Explain the principle of Watt's pendulum governor for a steam engine, and sketch the apparatus. Why is it important that the points of suspension of the arms should be near to the vertical axis of rotation? (15.)

13. Compare the crank with the eccentric. Show that they both produce the same motion. State reasons for employing one or the other in particular cases. (15.)

14. Sketch a longitudinal sectional elevation through the cylinder and condenser of a trunk engine, showing the air-pump and valves. How are the piston and trunk kept steam-tight? (20.)

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

21. Make a vertical transverse section through the nozzles and valves of a Cornish pumping engine, showing the positions of the stop or regulating, steam, equilibrium, and exhaust valves respectively, together with the ports of the cylinder and the passages for the distribution of steam. (25.)

22. Sketch and describe an equilibrium or balanced valve, and explain clearly the principle upon which the balance is obtained. Where the like construction is applied in a valve working in water, how is the weight of the valve balanced? (25.)

23. Describe, with sketches, the construction of an oscillating engine, and the method of distributing the steam. (30.)

24. An engine working without expansion has a piston of 144 square inches in area with a 12-inch stroke, and the number of double strokes per minute is 60. Steam is supplied at a temperature of 293° F. (the volume of 1 lb. of steam at 293° F. being 7 cubic feet), find the number of units of heat required per minute for supplying the steam from water at 60° F. (25.)

25. In a direct acting engine the crank is 2 feet in length, and the connecting rod is 8 feet; find the distance in inches of the piston from the middle point of its stroke, when the crank is at 90° from a dead centre. (20.)

26. Sketch a section through the eccentric, slide valve, and ports of a horizontal high pressure steam engine, working with a flat-faced locomotive D valve, *without lead*, and cutting off steam at ·5 of the stroke. What alteration should be effected in order that the steam may be cut off when the piston has completed ·7 of its stroke, there still being no lead? (30.)

27. Sketch Stephenson's double eccentric and link motion, name the several parts, and explain its action upon a slide valve. (35.)

28. Sketch a section through the cylinders and valve of a compound engine where one valve placed between the cylinders is used for the distribution of the steam. Explain the action of the valve by any sketches which may be necessary. (30.)

29. Describe some form of gauge for indicating steam pressure, and explain the principle of its action. How is such a gauge tested for accuracy? (25.)

30. Show by sketches and also explain the effect on an indicator diagram of:—1°, a leaky piston; 2°, contracted steam passages; 3°, a leaky condenser; 4°, deficiency of lap in the slide valve; 5°, deficiency of lead. (35.)

31. Why do ordinary steam boilers fail to utilize a large proportion of the heat developed in the complete combustion of the fuel employed? Sketch a longitudinal section through the fire box and tubes of a high pressure boiler. Describe the construction of the boiler, and show the method of staying the portions most likely to give way under pressure. (35.)

32. In a cylindrical steam boiler prove the formulæ for the forces tending to produce rupture of the material in the circumferential and longitudinal directions. (25.)

33. The travel of a slide valve is $5\frac{1}{4}$ inches, the outside lap $1\frac{1}{2}$ inches, the lead $\frac{3}{16}$ inch, and the exhaust lap $\frac{1}{4}$ inch, also the cut off is at $\frac{5}{8}$ of the stroke; determine the angle of advance of the eccentric, and give the maximum openings for steam and exhaust, assuming that the steam ports are $2\frac{1}{4}$ inches wide. (35.)

34. Sketch a section through the thrust block of a screw propeller, and state the materials employed for the different parts. Explain clearly the principle of construction and the difficulties to be overcome. (30.)

35. Compare the methods of working adopted in the Lenoir and Otto gas engines. Sketch and explain the forms of indicator diagram, exhibiting the successive operations in each type of engine. (25.)

36. Describe, with sketches, the slide valve of the Otto engine, and give a clear explanation of the manner in which the charging of the cylinder with gas and air is provided for. (35.)

37. Describe the pendulum governor of the Otto engine, and point out, by reference to sketches, the manner in which it acts. (25.)

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not permitted to attempt more than *six* questions.

The value attached to each question is shown in brackets after the question.

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41. Under what circumstances are balanced slide valves employed? Sketch and describe a balanced slide valve for the high pressure cylinder of a triple expansion engine. (60.)

42. A steam engine with a cylinder of D inches in diameter, receives steam at 80 lbs. absolute pressure per square inch, and the cut off is at $\frac{7}{8}$ of the stroke. Find an expression for the diameter of the cylinder of another engine with the same stroke and piston speed which develops the same horse power as the first engine, but which cuts off the steam at $\frac{1}{2}$ stroke. What would be the relative maximum stresses on the crank pin and crank shaft of the two engines when both transmit the same power, the inertia of the reciprocating parts and the obliquity of the connecting rod being neglected? (60.)

43. Describe, with sketches, Meyer's variable expansion valve. In an engine fitted therewith the steam is cut off by the main or distribution valve at $\frac{7}{8}$ of the stroke, the valve having a lead of $\frac{3}{32}$ inch, and the travel of the valve being 5 inches. Find the angle of advance, travel, and lap of the main valve. Set out and explain a diagram giving the relative motion of the main and expansion valves. (75).

44. Make a clear sketch of Joy's valve gear as applied to a locomotive or other engine and explain the manner in which the reversal of the engine is effected. Why does the lead remain constant throughout? (65.)

45. What physical law is expressed by the formulæ $pv = Rt$. Given $R = 53{\cdot}2$ foot pounds in the case of air; find its value for superheated steam, whose density as compared with air is ·622, and deduce the numerical value of the exponent in the equation to the curve for the adiabatic expansion of superheated steam. (60.)

46. Investigate fully the conditions under which a heat engine working between given temperatures shall perform the greatest amount of work possible. What are the obstacles met with in the endeavour to fulfil these conditions in a steam engine? (75.)

47. Describe, with sketches, the arrangement of cylinders in some form of compound locomotive engine. Sketch also a section through the Trick or Allen valve for a high pressure cylinder, and explain its action. How are the reversing gears arranged? (60.)

48. What would be the probable consumption of fuel per I. H. P. per hour in the most approved "simple condensing" and "triple expansion," engines respectively? State succinctly what are the differences, if any, in the initial or boiler pressures, in the grades of expansion, and in the construction of the slide valves of each cylinder of the triple engine, as compared with the single form, in order to obtain higher efficiency in the compounded engine. What reasons do you assign for the better result in the compound engine? (65.)

49. State generally the principle adopted in the cycle of operations of the Otto gas engine and the reasons why it works so advantageously. Describe also and sketch the arrangement of valves and passages which serve to admit gas and air in the proper proportions and to discharge the waste products from the cylinder. (60.)

SUBJECT XXIII. PHYSIOGRAPHY.

EXAMINERS, PROFESSOR JOHN W. JUDD, F.R.S.,
AND PROFESSOR J. NORMAN LOCKYER, F.R.S.

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *five* questions.

The value attached to each question is the same.

1. Name *five*, *very common*, rock-forming minerals, and state what chemical elements are present in each of them.
2. What differences occur in the apparent paths of the stars across the sky, as we proceed from the Equator to the Pole? What is the cause of this difference?
3. Explain the chief reasons why mercury is the liquid usually employed in the construction of—
    (*a.*) Barometers.
    (*b.*) Thermometers.
4. Explain by diagrams why the sun appears high in the sky at noon in summer and low at noon in winter.

5. How can the weight of air be determined? In what way is the pressure exercised by the atmosphere on the earth's surface, in consequence of its weight, stated? How is it that we are able to move about under the weight of the atmosphere?

6. What is sidereal and what is mean time?

7. State the grounds on which it is inferred that volcanic erruptions take place through fissures in the earth's crust.

8. Describe shortly the construction of an achromatic, astronomical telescope.

Second Stage or Advanced Examination.

INSTRUCTIONS.

You are permitted to *attempt* only *five* questions.

The value attached to each question is the same.

21. What is meant by the proper motions of the stars, and how has the distance of certain stars been ascertained?

22. Explain the precautions necessary in determining the temperature of the earth's crust at different depths—

    (*a*.) In mines and tunnels.
    (*b*.) In wells and bore-holes.

23. What is meant by magnetic declination and inclination respectively, and how may each be observed?

24. What are isotherms? What are the data required for drawing them upon a globe? Why do isotherms vary from parallels of latitude?

25. The sun's attraction at the earth's surface is much greater than that of the moon, yet the moon is the more important agent in producing tides. State the exact reason of this.

26. Explain the ordinary method used in determining the "mean annual rainfall" of a place, and state the chief sources of error in the observations which have to be made.

27. State what you know about Nebulæ.

28. What do you known about the Foraminifera and the part which they play in building up rock-masses.

Honours Examination.

INSTRUCTIONS.

You are permitted to attempt all, or any, of the questions.

The value attached to each question is the same.

41. How has the mass of the moon been determined from luni-solar precession?

42. Describe some recent results obtained by means of long-exposure photographs of the heavenly bodies.

43. What are geoisotherms? State what you know concerning the position of those within the earth's crust.

44. Describe the different methods which have been devised for recording the duration and intensity of sunshine on different days.

45. Give an account of the results which have been obtained by recent researches in connection with one of the following subjects:—
    (*a.*) Laplace's Hypothesis of the Origin of the sun and planets.
    (*b.*) The transmission of great air-waves during volcanic outbursts of exceptional violence.

SUBJECT XXIV. PRINCIPLES OF AGRICULTURE.

EXAMINERS, PROFESSOR HENRY TANNER, M.R.A.C., F.C.S., and PROFESSOR JOHN WRIGHTSON, M.R.A.C., F.C.S.

GENERAL INSTRUCTIONS.

If the Rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours paper, but you must confine yourself to one of them.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiners, and you are forbidden to write to them about your answers.

The examination in this subject lasts for three hours.

First Stage or Elementary Examination.

INSTRUCTIONS.

You are permitted to attempt only *eight* questions.

Each question admits of an answer carrying an equal number of marks.

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1. **Name nine constituents of a fertile soil which are taken up by plants.**
2. **Why are clay soils usually rich? What are the causes of barrenness in sandy and peaty soils?**
3. **Why is farmyard manure univerally esteemed as a fertiliser?**
4. **Jethro Tull found that he was able to grow wheat year after year without manure, provided that he thoroughly tilled the soil. Explain this fact, and say upon what descriptions of soil such a course might be adopted with success.**
5. **Give a three-course, a four-course, and a five-course rotation of crops.**
6. **Why are turnips and straw a good combination of foods for cattle?**
7. **What substances, and in what quantities, would you add to turnips and straw in order to more quickly fatten a bullock?**
8. **At what periods of the year would you sow wheat, barley, winter vetches (tares), winter beans, mangle wurzel, swedes, and white turnips? In answering this question state what particular district or locality you have in view.**
9. **How would you judge wheat and barley, respectively, to be fit to cut? On what considerations is the difference of practice in cutting these two cereals based?**
10. **Why is a corn crop more exhausting to the land than a root crop? Is this invariably the case?**
11. **What are the advantages of steam cultivation over ordinary horse tillage? Are these advantages more likely to be realised on "heavy" or on "light" soils, and why?**
12. **Show, by examples taken from the practice of good farmers, that light land requires to be rendered firm or solid before it is fit to grow corn crops.**

Second Stage or Advanced Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are permitted to attempt only *six* questions.

Each question admits of an answer carrying an equal number of marks.

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21. Certain mineral matters are known to be necessary as plant-food. Is a soil always fertile when such plant-food is present? If not, why not?

22. What proof is there that different crops require different supplies of plant-food?

23. What are the conditions necessary for the production of farmyard manure in its best condition?

24. In what respects have superphosphates and reduced superphosphates a similarity of influence on crops, and wherein do they differ?

25. What principles should regulate the use of lime as a fertiliser?

26. How is plant-growth influenced, (*a*) favourably, and (*b*) unfavourably, by water in or upon the soil?

27. Give instances of good and bad rotations of crops, explaining why you consider them "good" and "bad" respectively.

28. What principles would guide you in determining the shelter which is necessary for the proper care of farm stock?

29. How does regularity in the supply of proper food, influence the meat produced by its use?

30. What do you understand by the food of stock being complete in its character?

31. How would you conduct the operation of churning, and in what way should the butter be treated when removed from the churn?

32. What are the conditions which are absolutely necessary for the successful hatching of eggs?

33. What advantages result from keeping bees on a farm? State (very briefly) the system you would adopt for securing these advantages?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions at the head of the Elementary paper.

You are not to attempt more than *six* questions in this paper.

Each question admits of an answer carrying an equal number of marks.

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41. If a linseed cake contain 28·1 per cent. of albuminoids, 12 per cent. of fat, and 30·3 per cent. of soluble carbohydrates, what will be the albuminoid ratio of the cake in question?

42. Prescribe a combination of foods which shall preserve approximately the most suitable albuminoid ratio (1) for growing cattle, (2) for fattening cattle.

43. Name the most important changes in the composition of cattle and sheep which take place during the fattening process.

44. Briefly describe the following breeds of cattle.

    (1) Shorthorns;
    (2) Herefords;
    (3) Devons;
    (4) Angus, or Aberdeens;
    (5) Ayrshires;
    (6) Sussex.

45. What are the chief objections to growing root crops on clay land? and what means would you suggest for cropping such lands, with a view to maintaining live stock and at the same time continuing to grow wheat and other grain crops in rotation.

46. Upon what principle is the system of deep setting of milk founded? Describe a good system of deep setting of milk.

47. Fully describe a good system of making butter. In answering this question you are to mention the most modern appliances employed in making high-class butter.

48. Describe the process of ensilage as carried out in silos and in stacks, and clearly point out how the process may be regulated so as to make sour and sweet silage.

49. What scientific reasons would, in your estimation, regulate the period for cutting grass for hay, consuming fodder crops, or harvesting corn crops?

50. Prescribe suitable dressings of manure, giving the quantities per acre and times of application for—
    (1) Swedish turnips;
    (2) Mangel wurzel;
    (3) Wheat;
    (4) Grass land.

51. Why is the percentage given of albuminoids in analyses of root crops to be received with caution? Why is the proportion given of fat in analyses of root crops to be distrusted?

52. Give some reasons for and against the liberal use of "roots" as a food for cattle and sheep.

SUBJECT XXV. HYGIENE.

EXAMINER, PROFESSOR W. H. CORFIELD, M.A., M.D. (OXON).

GENERAL INSTRUCTIONS.

If the rules are not attended to, the paper will be cancelled.

You may take the Elementary, or the Advanced, or the Honours Paper, but you must confine yourself to one of them. All candidates in the Elementary or in the Advanced Stage are required to answer the questions in Elementary Human Physiology.

Put the number of the question before your answer.

You are to confine your answers *strictly* to the questions proposed.

Your name is not given to the Examiner, and you are forbidden to write to him about your answers.

The examination in this subject lasts for three hours.

Elementary Human Physiology.

a. Give a brief description of the heart, and describe its action.

b. Describe the structure of the stomach and the process of digestion in it.

First Stage or Elementary Examination.

INSTRUCTIONS.

Read the General Instructions on page 1.

You must answer the questions on Elementary Human Physiology, and you are also permitted to *attempt six*, but not more than six, of the following questions.

The same value is attached to each question.

1. What are the carbohydrates? How are they disposed of in the system? What are the chief foods containing them?
2. What are the characteristics of good drinking water? From what sources is such water obtained?
3. How may water stored in cisterns become impure?
4. What impurities in air are caused by various manufacturing processes?
5. Describe some simple methods of ventilating rooms. Illustrate your answer by sketches.
6. Why does the ground under houses require to be drained? What is meant by a damp-proof course.
7. What is soap? Of what use is it in cleansing the skin?
8. In what various ways may the action of the bowels be promoted? What is the importance of this?
9. What are the most important substances contained in the tea-leaf? How should good tea be prepared? What is its action on the system?
10. Describe Sylvester's method of inducing artificial respiration.

Second Stage or Advanced Examination.

Instructions.

Read the General Instructions on page 1.

You must answer the questions on Elementary Human Physiology, and you are also permitted to *attempt four,* but not more than four, of the following questions.

The same value is attached to each question.

21. What are the quantities of food substances (proximate constituents) in the following diet? Lean beef, 6 oz.; bread, 20 oz.; potatoes, 10 oz.; Milk 10 oz.; and water, 50 oz. Is it an economical diet or not?

22. Describe the intermittent system of water service. What are its advantages or disadvantages as compared with the constant system?

23. What are the methods of ventilation by aspiration? State their advantages and disadvantages.

24. What are the uses of soil-pipes? How should they be constructed, ventilated, and connected with the house-drain? Illustrate your answer by sketches.

25. Describe in detail a grate or stove provided with an arrangement for the introduction of warm fresh air.

26. How much air-space and how much floor-space per head would you provide for in a school-room? How would you arrange the lighting?

27. What are the causes of Rheumatic Fever? What are its dangers? What precautions should be taken during convalescence?

Honours Examination.

INSTRUCTIONS.

Read the General Instructions on page 1.
You are permitted to *attempt* only *four* questions.
The same value is attached to each question.

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41. Describe in detail the precautions to be taken in laying a house-drain.

42. What are the processes employed at "Alkali-works"? What nuisances may be caused by them, and how may they be prevented?

43. What are the provisions of the Public Health Act for the prevention of the spread of infectious diseases?

44. What is an Artesian Well? State the various geological conditions under which it is advantageous to sink such a well. What are the characters of the waters obtained?

45. What are the distinctions between typhus and typhoid fevers? Contrast the methods of prevention to be adopted.

46. What fallacies must be guarded against in using mortality statistics for comparative purposes? The population of one district being 20,000, and its death-rate 30 per 1,000 per annum, and that of another 30,000, with a death-rate of 20 per 1,000 per annum, what is the death-rate of the combined districts?

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